New York State Education Department

NEW YORK STATE MUSEUM

58th ANNUAL REPORT

1904

VOL. 1

REPORT OF THE DIRECTOR 1904

AND

APPENDIX 1

TRANSMITTED TO THE LEGISLATURE FEBRUARY 15, 1905

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NEW YORK STATE EDUCATION DEPARTMENT
1906

STATE OF NEW YORK

EDUCATION DEPARTMENT

Regents of the University

1904

With years when terms expire

STATE OF NEW YORK

No. 12

IN SENATE

FEBRUARY 15, 1905

58th ANNUAL REPORT

OF THE

NEW YORK STATE MUSEUM

To the Legislature of the State of New York

We have the honor to submit, pursuant to law, as the 58th annual report of the New York State Museum, the report of the Director of the museum including that of the State Geologist and Paleontologist, and reports of the Entomologist and of the Botanist, with appendixes.

WHITELAW REID
Chancellor of the University

A. S. DRAPER
Commissioner of Education

CONTENTS

VOLUME 1

Report of the Director 1904

	PAGE
Preface	5
Geology and paleontology	12
Mineralogy	33
Botany	33
Entomology	34
Zoology	36
Archeology	36
Publications	36
Collections	38
Accessions	39
Localities of American Paleozoic fossils	55
Supplement to list of type specimens of Paleozoic fossils	58
Specimens of Tertiary fossils from the Pebas of Maranhao river, Brazil	131
Index	135

Appendix 1

Museum bulletins 83, 84, 95, 96

1 Geology
- 7 (83) Pleistocene Geology of the Mooers Quadrangle. J. B. Woodworth
- 8 (84) Ancient Water Levels of the Champlain and Hudson Valleys. J. B. Woodworth
- 9 (95) Geology of the Northern Adirondack Region. H. P. Cushing
- 10 (96) Geology of the Paradox Lake Quadrangle. I. H. Ogilvie

VOLUME 2

Appendix 2

Museum bulletins 85, 93

2 Economic geology
- 12 (85) Hydrology of New York State. G. W. Rafter
- 13 (93) Mining and Quarry Industry of New York. D. H. Newland

VOLUME 3

Appendix 3

Museum bulletins 81, 82, 92, 90

3 Paleontology
- 11 (81) Watkins and Elmira Quadrangles. J. M. Clarke D. D. Luther
- 12 (82) Geologic Map of the Tully Quadrangle. J. M. Clarke
- 13 (92) Guide to the Geology and Paleontology of the Schoharie Region. A. W. Grabau
- 14 (90) Cephalopoda of Beekmantown and Chazy Formations of Champlain Basin. Rudolf Ruedemann

VOLUME 4

Appendixes 4–6

Museum bulletins 87, 88, 89, 91, 94

4 Zoology
- 11 (88) Check List of the Mollusca of New York. E. J. Letson
- 12 (91) Higher Crustacea of New York City. F. C. Paulmier

5 Archeology
- 10 (87) Perch Lake Mounds. W. M. Beauchamp
- 11 (89) Aboriginal Use of Wood in New York. W. M. Beauchamp

6 Botany
- 8 (94) Report of the State Botanist 1904. C. H. Peck

VOLUME 5

Appendix 7

Museum bulletins 86, 97

7 Entomology
- 23 (86) May Flies and Midges of New York. J. G. Needham *and others*
- 24 (97) 20th Report of the State Entomologist 1904. E. P. Felt

New York State Education Department
Science Division, Nov. 1, 1904

To the Honorable Andrew S. Draper LL.D.
Commissioner of Education

SIR: I have the honor to submit herewith my reports as Director of the Science Division and of the State Museum, and as State Geologist and Paleontologist, for the fiscal year ending Sep. 30, 1904.

Respectfully yours
JOHN M. CLARKE

New York State Museum

John M. Clarke Director

REPORT OF THE DIRECTOR 1904

The New York State Museum was organized as the New York State Cabinet of Natural History. The scientific collections which formed the nucleus of this organization were brought together in the course of the Natural History Survey of the State of New York which commenced in 1836 and closed by the rendition of the final reports in 1843. In the organization of that survey no provision was made for the conservation or custody of such materials as should be acquired by the various members of its staff. It was however impossible that scientific results of value should be achieved without the aggregation of extensive collections. In some measure the specimens thus brought together seem through want of provision for their custody and fault of storage facilities, to have passed into the possession of the collectors themselves.

During the progress of the Natural History Survey the Secretary of State, who was officially charged with its supervision, considered that the various collections might be accommodated in a room in the third story of the old Capitol by throwing two committee rooms into one. This arrangement proving inadequate, in 1840 Governor Seward in response to a memorial from the geologists "urging the importance of providing suitable rooms or a separate building for the collections made during the survey" recommended that the old State Hall be used for that purpose.

After the close of the survey in 1843 the Governor was authorized by the Legislature to continue the services of one or both of the geologists who were living in Albany, Ebenezer Emmons and James Hall, for the purpose of completing and arranging the collections of specimens in the old State Hall and in accordance with this authority Dr Emmons was for a time charged with this arrangement. The building thus referred to as the old State Hall followed on the same site the original building

erected for state offices in 1797 during the governorship of John Jay, and it was made over in 1855 into the present Geological Hall.

By virtue of an act passed May 10, 1845, and constituting chapter 179 of the laws of that year, the Regents of the University, to whom was committed the care of the "State Cabinet of Natural History" were authorized to make a suitable provision for the safe-keeping of the collections and a small appropriation was made to defray the expenses of custodianship. Under the authority thus vested in the Regents of the University, annual reports were begun upon the condition of the State Cabinet of Natural History, the first of these being dated Ap. 11, 1848. The administration of the affairs of the natural history collections was carried on as an independent charge of the Regents for many years, during which period the scientific investigations which were being prosecuted by Prof. James Hall in paleontology, Dr Ebenezer Emmons in agriculture and geology, and by Dr Asa Fitch in entomology were entirely independent of the organization of the State Cabinet.

The custodianship of the collections was first assigned to John Washington Taylor who was succeeded by John Gebhard jr and he, in 1859, was followed by Col. Ezekiel Jewett. After seven years of service Colonel Jewett resigned and in 1866 Professor Hall was made curator of the State Cabinet.

To this time the development of the museum along truly scientific lines had been but slight. The collections had failed to exemplify the progress of scientific investigations in the State, and although it was supposed that they would continue to be the depository of the scientific work still in progress this did not altogether prove to be the case. Provision was made for their development and increase only by the most meager annual appropriations and the condition aroused the solicitude both of the Board of Regents and of the friends of science throughout the State. In 1865 the Legislature passed a series of resolutions tending to the expansion of the State Cabinet, and following this the Regents of the University addressed a letter to numerous scientific men throughout the country asking suggestions as to the best mode of putting in force the objects of the Legislature as expressed in the resolutions referred to. In consequence thereof the Regents in the annual report dated 1866 submitted a "plan for placing the State Cabinet of Natural History in the condition required by the present state of science; to maintain it in full efficiency as a museum of scientific and practical geology and comparative zoology," com-

municating therewith replies to their circular letter from various scientific men of eminence. The recommendations in this report became the first steps toward an improved condition and a recognition of the necessity for regarding the museum as the seat of scientific collections which were not to remain stationary but to be increased and elaborated in every department. Action upon the report of the Regents was not formally taken by the Legislature until 1870 when a law was passed organizing the Cabinet as the "State Museum of Natural History" and appropriating $10,000 annually to provide for the salary of the director and his assistants and for the increase and preservation of the collections; at this time also the additional sum of $1500 was annually appropriated for the salary of a botanist.

The work in the paleontologic and agricultural departments, continued from the old Natural History Survey was, as just observed, carried on independently of the State Cabinet, though keeping the same rooms therewith in the old State Hall until 1845. The constantly widening scope and importance of the work in paleontology threw upon Professor Hall the necessity of finding quarters for the extensive acquisitions in this department, and he provided two buildings at his own cost for the disposition of the immense collections brought together by him and for the accommodation of his growing staff of assistants.

The labors of Dr Asa Fitch as entomologist to the State Agricultural Society closed in 1870. The State Agricultural Society was the direct outcome of the Agricultural Department of the original Natural History Survey. In 1874 Joseph A. Lintner, then an assistant in the museum, was placed in charge of the entomologic work and he was formally appointed State Entomologist by the Governor in 1880.

In 1883, by legislative enactment, the work of the State Museum of Natural History, of the State Geologist and Paleontologist, of the State Botanist and of the State Entomologist was brought together under the charge of the Regents of the University, each becoming a department of the Museum. Under this provision, constituting chapter 355, laws of 1883, a scientific staff was created subject to appointment by the trustees to consist of a director "who may also be State Geologist" and "of three assistants, together with such special assistants as may be necessary, whose compensation shall be fixed from time to time by the said trustees, together with the State Geologist, State Entomolo-

gist and Botanist as these officers are now defined and provided for by law."

Under this incorporation of the departments into the general organization of the State Museum the scientific staff became in a certain definite sense subsidiary or contributory to the general functions of the Museum as a depository of scientific collections.

The same law recognized the fact that the Geological Hall was insufficient both in capacity and in construction for the accommodation of the greatly increased collections of the State Museum and the scientific work of its departments, and authorized the Regents of the University to take possession of the present State Hall as its rooms should be vacated by the state officers who were to be accommodated in the new Capitol. In pursuance of this provision several of the rooms in the State Hall were in 1886 occupied by the staff of the State Geologist and Paleontologist and by the State Botanist, and the more valuable and typical portions of the paleontologic and botanic collections removed thereto. It subsequently proved impracticable to acquire full possession of the State Hall on account of the reluctance of its occupants to remove to other quarters, but the office of the State Paleontologist and the larger part of the collections in paleontology have been in this building from that date to the present.

In 1889 the State Museum was made an integral part of the University of the State of New York, and the section of the law which specially relates to the affairs of the Museum says "all scientific specimens and collections, works of art, objects of historic interest and similar property appropriate to a general museum if owned by the State and not placed in other custody by specific law shall constitute the State Museum, and one of its officers shall annually inspect all such property not kept in the State Museum rooms and the annual report of the Museum to the Legislature shall include summaries of such property with its location and any needed recommendation as to its safety or usefulness."

Together with the other departments of the University, the Museum became a constitutional body in 1895, and in the revised University law of 1896 the functions of the organization are defined as already given.

In 1885 Dr John C. Smock was appointed assistant in charge of the State Museum under the directorship of Prof. James Hall. Prof. James Hall resigned his position as Director of the State

Museum in 1894 and was succeeded by Dr F. J. H. Merrill who had previously held the position of assistant director from 1890. Upon the death of Professor Hall in 1898 Dr Merrill was also appointed State Geologist.

In the fusion of the University of the State of New York with the Department of Public Instruction by the action of the Legislature of 1904 and the resultant erection therefrom of the Education Department, the scientific interests of the resultant Department were constituted a separate division termed the Division of Science. The scientific officers of this division, the State Geologist and Paleontologist, the State Botanist and the State Entomologist constitute heads of sections, and the State Museum is relegated to its normal and proper function as a depository of the materials acquired by the scientific corps of the division. The Museum thus resumes the relation to the scientific work of the State that it had in the first days of its history; instead of being itself the titular organization under which scientific work is carried forward, the scientific work as represented by its various department officers is now given paramount importance. To the directorship of the Division of Science, by action of the Commissioner of Education and the Board of Regents, John M. Clarke, formerly assistant State Geologist and Paleontologist and at that time holding the position of State Paleontologist, was appointed. At this time also the offices of State Geologist and State Paleontologist were recombined and united with that of director as had been the condition during the tenure of Professor Hall from 1866 to 1894. As at present constituted the scientific staff of the Division of Science consists of the following officers: the State Geologist and Paleontologist, the State Botanist and State Entomologist with their various assistants and also a mineralogist, zoologist and archeologist. The collections in structural geology and economic geology are in the Geological Hall; those in paleontology are chiefly in the State Hall, though collections of considerable extent and value are also in the Geological Hall; collections in mineralogy, the office of the State Botanist and the state herbarium and the office of the State Entomologist and his collections and all other collections in zoology and biology are in the Geological Hall. The collections in archeology are chiefly in the corridors of the Capitol on the fourth floor at the head of the western staircase, though additional collections of considerable value are in the Geological Hall.

The permanent staff of the Science Division at the present time consists of 22 members; the appropriation for the maintenance of the work for the fiscal year 1904-5 is $39,640, and, though this is really inadequate to the requirements of such a scientific institution, it nevertheless serves to maintain active progress in various lines of scientific investigation, and to increase the interest and the value of the scientific collections.

The organization and staff (permanent and temporary) of the Division of Science as at present constituted are:

Administration

John M. Clarke, *Director*
Jacob Van Deloo, *Director's clerk*

Geology and Paleontology

John M. Clarke, *State Geologist and Paleontoligist*
David H. Newland, *Assistant State Geologist*
Rudolf Ruedemann Ph.D., *Assistant State Paleontologist*
Henry H. Hindshaw B.S., *Assistant in Economic Geology*
D. Dana Luther, *Field Geologist*
Herbert P. Whitlock C.E., *Mineralogist*
George S. Barkentin, *Draftsman*
William S. Barkentin, *Lithographer*
Joseph Morje, *1st clerk*
H. C. Wardell, *Preparator*
Edward C. Kenny, *Stenographer*
Clarence A. Trask, *Clerk*
Martin Sheehy, *Machinist*

Temporary assistants

PRECAMBRIC GEOLOGY

Prof. H. P. Cushing, Adelbert College

STRATIGRAPHIC GEOLOGY

Prof. A. W. Grabau, Columbia University
C. A. Hartnagel, Columbia University
M. J. Goldman, Columbia University

GEOGRAPHIC GEOLOGY

Prof. Herman L. Fairchild, University of Rochester
Prof. J. B. Woodworth, Harvard University

HYDROLOGY

George W. Rafter C.E., Rochester

PALEONTOLOGY

Dr C. R. Eastman, Harvard University
David White, United States Geological Survey
Edwin Kirk, Columbia University
Frederick Braun, Brooklyn

Botany

Charles H. Peck M.A., *State Botanist*

Temporary assistant

Stewart H. Burnham, Glens Falls

Entomology

Ephraim Porter Felt B.S. D.Sc., *State Entomologist*
D. B. Young, *Assistant State Entomologist*
I. L. Nixon, *Assistant*
Anna M. Tolhurst, *Stenographer*
George W. V. Spellacy, *Page*

Temporary assistants

Prof. J. G. Needham, Lake Forest University
Prof. Herbert Osborn, Columbus O.
E. P. Van Duzee, Buffalo

Zoology

Frederick C. Paulmier M.S. Ph.D., *Zoologist*

Temporary assistant

William C. Richard, Waterford

Archeology

William M. Beauchamp S.T.D., *Archeologist*

REPORT FOR 1904

The director's report is substantially a presentation of the reports of the heads of the various scientific sections and these I submit herewith. They are followed by a general statement as to the condition of the scientific collections.

GEOLOGY AND PALEONTOLOGY

The duties of the geologist and paleontologist divide themselves into field operations and office work. In view of the small number of workers on the permanent scientific staff it has been our practice to enlist, so far as our appropriations and the enthusiasm of others have permitted, the services of temporary aids recognized as expert in their various lines of scientific interest. With such assistance we are able to meet, in some measure, the demand for the more exact knowledge of our geologic formations and mineral deposits commensurate with the area and growing commercial interests of the State. It is the good fortune of the State to have been able to enlist in this scientific enterprise so many workers of distinguished ability and recognized authority, and it is a source of congratulation that circumstances permit us to avail ourselves of so high a grade of scientific talent without involving the State in any serious obligation therefor. To these gentlemen we owe much, for sometimes their work is carried on wholly without remuneration and at others for a compensation so insufficient that the pleasure and satisfaction in doing the work has remained the chief return from their labors.

Operations in the field

Precambric geology

Geology of Long lake quadrangle. Prof. H. P. Cushing, who for several years has been concerned with the study of the crystalline rocks of the Adirondacks, has this year devoted his time to the areal mapping of the Long lake quadrangle. This work was substantially finished.

The Long lake quadrangle is centrally located in the mountain region and is of exceptional interest in that practically all the Precambric formations of the Adirondack area are there present with their characteristic topographic expression. The northeastern part of this quadrangle is occupied by an extensive mass of anorthosite, the northwestern by an equally large mass of syenite, their boundary running southeast across the area for a

distance of 10 miles. The boundary has been carefully followed and plotted. Both of these masses become more obscure and gneissoid near their edges, and the usually weathered phases of the resulting rocks are closely alike and difficult to distinguish in the field. Considerable masses of syenite are found within the anorthosite area, and the reverse is also true. It is not possible that both were extruded at the same time but decisive evidence has not been acquired, although in all probability the syenite is the younger. The syenite is frequently cut by a younger granite, small dikes of which are also found occasionally in the anorthosite.

The southern half of the quadrangle is occupied by gneisses with an extensive development of the peculiar schists and gneisses which are old sediments of Grenville age. Crystalline limestones occur with these in some measure. The extensive development of the Grenville series in this area was unexpected, and it will be necessary to revise our previous views as to the extent of these rocks in the immediate region of the mountains. The gneisses are mainly red and biotitic, probably of the composition of granites though showing a considerable variation. With these are amphibolites which locally pass into hyperite gabbros of which the amphibolites, in part at least, are a metamorphosed phase. In the southwest the gneisses differ somewhat and are to some extent involved with the granite. The granites are also found cutting the Grenville rocks. These gneisses are free from admixture with characteristic Grenville rocks and seem to represent a whole distinct rock series, though no exposures were found which gave any clue to the relations of the two. A single large diabase dike was located on Camp island in Long lake.

In the north half of the sheet the region of the high Adirondacks is touched on the east; midway is the low ground of the lake belt, here rather poorly defined, west of which are higher syenite peaks. On the south the gneisses furnish more rounded hills than do the eruptives and the Grenville rocks are mainly found in the valley levels.

Stratigraphic geology

Areal maps. The work of producing stratigraphic maps on the topographic base has progressed in several parts of the State. In these maps we have endeavored to make the stratigraphic

determinations as refined as our knowwledge justifies. Experience has taught us that the representation upon maps of this scale, of the grouping of the rocks as recognized in the older classifications leaves very much to be desired. The value of such maps is chiefly their usefulness to the student of local conditions. They are therefore made to represent such local conditions even though these may not appear in adjoining regions. The refined coloration has naturally involved the closest work in stratigraphic determinations and it has also introduced an inevitable incongruity in coloration. So far as the color scheme is concerned and the number of shades and patterns which the plan of the work makes it necessary to introduce, it may be said that each map is complete in itself, and probably no color scheme could be devised which would be sufficiently elastic to lend itself to the production of a series of maps on this scale with the refinement of stratigraphic determination that we are practising.

Buffalo quadrangle. The preparation of this map has been brought to completion by D. D. Luther. The work was begun some years ago by Prof. I. P. Bishop and it seemed well to go over the ground again in the hope of making the stratigraphic determinations somewhat more detailed. This Mr Luther has done and has been aided therein by Professor Bishop. This map will be submitted for publication during the coming year.

Penn Yan and Hammondsport quadrangles. These two quadrangles lie one to the north of the other and have been entirely mapped this year by D. D. Luther. This work has been in continuation of the Canadaigua-Naples map issued last year and the Watkins-Elmira map which is now in press, the former at the west and the latter at the east of this region. These quadrangles have been taken up in north and south pairs with the idea of covering a pretty full sweep of the Devonic rock series. The meridional distance represented by one of these double sheets is 35 miles. The Penn Yan-Hammondsport map will be issued soon, accompanied by an explanation of the stratigraphic determinations there made.

Rochester quadrangle. The preparation of this map was begun by C. A. Hartnagel and carried well toward completion. Mr Hartnagel has had the benefit of such local cooperation as was available and acknowledges his obligation in this regard to Prof. H. L. Fairchild and Prof. A. L. Arey.

Tully quadrangle. This area lies directly south of Syracuse and is the chief collecting ground for the students of geology and paleontology in that center. The map has been prepared

specially in the hope that it may prove of use to the residents of that city and vicinity. I reported last year that the work on this map was essentially completed and have now to record that the map is issuing from the press and constitutes Museum bulletin 82.

Geology of the Schoharie region. In connection with the preparation of a *Guide to the Geology and Stratigraphy of the Schoharie Region,* Prof. A. W. Grabau has prepared an areal map of this region. I have previously referred to the fact that the Schoharie creek is the classical ground of New York geology. It was here that the Gebhards, father and son, labored before the organization of the geological survey of 1836-42. The classification of the rocks in the fine exposures along this creek was adopted by the state geologists very much as it had been worked out by the Gebhards. To the present time there has been no adequate geologic map of the region.

Professor Grabau's work in this region was not completed in 1903. His determinations have carried him in some measure afield from the locality referred to in order to coordinate his results, and during the early part of the season he made some examinations in the country extending from the Indian Ladder to Rosendale, Ulster co. Subsequently the Schoharie region was reviewed with the object of determining certain points involving the genesis of the rock formations and their bearing upon the paleogeography of the district. The Schoharie map and the report to accompany it are now in course of publication.

Cobleskill formation. Mr Hartnagel, who had previously reported upon the extent and characters of this formation from Ulster county west to Buffalo, has continued his investigations farther to the southeast and to the New Jersey line. The determination of this formation, which has heretofore been barely recognized as a member of the New York series, has constituted an important step forward in New York stratigraphy. Lying near the border line of the great Siluric and Devonic series it has required extremely cautious treatment and Mr Hartnagel's investigations upon this theme have helped to throw light on the extension of certain of our formations into New Jersey and have indicated the equivalence of some of the New Jersey formations with our own.

The section he has studied with particular attention extends from High Falls, Ulster co., southward through Sullivan and Orange counties as far as the Nearpass quarry, which is a short

distance from the state line in New Jersey. At High Falls the Cobleskill limestone is underlain by a cement bed and this rests on a thin fossiliferous bed of shaly limestone which in a previous report has been regarded equivalent to the Wilbur limestone. Southwestward from High Falls neither the Cobleskill limestone nor any immediately preceding fossiliferous beds have been recorded. In New Jersey however the presence of the Cobleskill, which is the equivalent of the Niagara of Dr Barrett, has been recognized for some time, and at the Nearpass quarry the Decker Ferry beds which lie directly below the Cobleskill are highly fossiliferous. Here however there is no cement bed present as there is at High Falls. Below the Decker Ferry beds in New Jersey lie the Bossardville limestone and the Poxino Island shale, but no outcrops of these are to be found in New York in Orange county. The Cobleskill and the upper part of the Decker Ferry formation are shown in the ledges east of Cuddebackville. Northeastward from this section no other outcrops of these formations were observed till reaching the village of Kerhonkson, Ulster co., where the Cobleskill is seen just north of the village. Thence the formation was readily traced to near Accord where both the Cobleskill and the Decker Ferry are well shown in the railroad cut and the bank of the canal. These exposures of the Decker Ferry formation are the best that have been observed in the State. At Accord no cement is found below the Cobleskill as at High Falls a few miles to the northeast. Thus it is evident that in the comparative short distance between High Falls and Accord this cement bed becomes so calcareous as to be changed to a limestone, while the presence of the typical Decker Ferry fossils just below the cement at High Falls indicates that this cement bed is the stratigraphic equivalent of a portion of the Decker Ferry formation as developed at Accord and farther south.

Shawangunk conglomerate. A second problem has presented itself during the progress of these investigations, namely, the age of the unfossiliferous formations lying below the cement and the Decker Ferry formation. While the Cobleskill limestone was still regarded as equivalent to the Niagaran the underlying formations could not be interpreted as later than Medina and Clinton. As we now recognize the Cobleskill to be above the Salina, the age of these unfossiliferous deposits was brought in question. The quartzites and shales resting upon the Shawangunk grit and which have generally been correlated with the Medina and

Clinton are now regarded as of Salina age. The study of the Shawangunk grit throws a shadow of doubt upon the time-honored correlation of these beds with the Oneida conglomerate and it will be a matter for investigation whether they may not, in part at least, represent sedimentation equivalent to a later period, possibly of the date of the Salina.

Stratigraphy of the Watertown region. Some preliminary work has been done along the region of the Black river in study of the development and subdivision of the Trenton, Black River and Lowville limestones. This work was done by Mr M. F. Goldman under the general supervision of Professor Grabau. Mr Goldman's work is based chiefly upon the collections of fossils made by him and these will be determined with a view to carrying out the stratigraphic subdivisions as far as is practicable. The investigations have indicated that the contact of the Lowville limestone with the crystalline rocks is an overlap of more ancient sediments transgressing upon the crystallines.

Correlation studies

Early Devonic of eastern America. The rapid growth of geologic knowledge has long made it evident that problems arising from and distinctly pertaining to the geology of New York can not be satisfactorily solved from the evidence presented within our political boundaries only. Some of the most striking developments of New York geology are to be found outside these boundaries, and we have, as occasion required, sought this information where it is best presented. The Paleontologist has devoted much time and thought to questions relating to the origin of the ancient faunas of New York, their point of ingress into the State and their direction of departure from it, problems which lead to the reconstruction of our ancient geography and the determination of the waterways or marine channels through which life circulated freely during the deposition of the New York sediments. In pursuance of the objects of these studies collections have been made and field work done in the extension of the New York rocks to the northeast, into the Province of Quebec. Reference has been previously made to these studies and we have now brought together from these eastern manifestations of New York rocks extensive and unique exemplifications of our New York early Devonic faunas.

The region referred to, so far as its fossil faunas are concerned is practically virgin field, and the work that has been done and is now under way in view of detailed study has been undertaken with the approbation of the official geologists of Canada. The work promises well and it is believed will make a fruitful return to geologic science. This line of investigation has been substantially aided by volunteer contributions from equally interesting and heretofore unexploited localities in northern Maine. It is believed that the near future will enable us to present a somewhat detailed report upon the data that have thus been acquired.

Guelph fauna. A year ago we issued a memoir on the Guelph formation and fauna in New York. It was the exploitation of a practically new member of the New York formations. During the past year the operations of the Canadian power companies at Niagara Falls laid bare large areas of the river bed and the laying of the enormous 18 foot pipes of the Ontario Power Co. required tremendous excavations into the bed rock. These upper layers of the dolomites lying above the crest of the falls and forming the reefs of the upper rapids have afforded us evidences of the presence of the Guelph fauna which have not before been observed and are therefore recorded in this place.

Geographic geology

Hudson and Champlain valleys. Prof. J. B. Woodworth has continued the investigations begun in a previous year upon problems relating to the determination of the postglacial high water levels of the northern Hudson valley and the Lake Champlain valley, the object of the work being to illustrate the mode and direction of outflow and discharge of the glacial and postglacial waters of that region and the manner of deposition of the ancient shore lines and beaches. In pursuance of this work Professor Woodworth entered the field in Clinton county in July, stopping at Bellows Falls Vt. for the purpose of examining the terraces of the Connecticut river as an aid to the understanding of similar features in the Hudson valley and also at Brandon Vt. to inspect the decomposed Tertiary and the older rocks in their relations to the glacial drift. Examination was made of Trembleau mountain near Port Kent and of the vicinity of Plattsburg where such shore phenomena occur. Three weeks were spent in making a detailed contour map of what, in this survey, has been denominated " Cobblestone hill," a washed ridge of boulders and cobbles

near West Chazy, the main features of which have been described and illustrated in a report now in press. Subsequently a reconnaissance was made of certain points on the Vermont side of Lake Champlain which led Professor Woodworth to Richford and over the international boundary to Abbot's Corners, Quebec, thence southward to Milton and the basin of the Winooski river lying east of the Green mountains. It was ascertained that a glacial lake at one time occupied this basin, as probably one also did that of the Lamoille river in a similar geographic relation to the retreating ice sheet of the Wisconsin epoch. The occurrence of glacial clays in the Winooski valley at higher levels than they are found in the Champlain valley appears entirely explicable in the view that this lake was in existence while the ice in the Champlain valley blocked the discharge through the Winooski gap in the Green mountains, thus forcing the lake to drain eastward across the head-water region of the Winooski into the Connecticut river. As soon as the ice depassed the Winooski gorge the lake drained into the glacial predecessor of Lake Champlain and fell to its level. A similar history must have attended the drainage of the Lamoille basin. The high level of the lake clays in the Winooski basin therefore does not demand the existence of a contemporaneous lake in the Champlain valley at so high a level. The reconnaissance served also to make it probable that the glacial lakes in the Champlain valley did not drain eastward at any time through the gaps in the Green mountains into the Connecticut.

Postglacial faults. Later in the season Professor Woodworth took up the investigation of the postglacial faults in the slate region east of the Hudson in order to determine the role of these displacements in the general northward rise of the country during and since the disappearance of the ice. It will appear in his report that these recent geologic fractures are found at intervals from Troy southward to the vicinity of Hyde Park and from the Hudson river to the base of the Taconic range, and that they indicate an uplift of the country on the east in a manner to suggest that these ancient mountain ranges on the eastern border of the State are still growing.

Glacial and postglacial drainage in western New York. Prof. H. L. Fairchild has studied the drainage features of the glacial lakes in western and central New York with reference to the altitude and direction of overflow of the glacial waters. These

operations were in large measure in continuation of his previous work. A review was made of some drainage features in the Erie basin between the state line and Hamburg, and a rapid examination was made of the Finger Lake basins primarily with reference to the altitude and overflow of the glacial waters, involving also the interesting discovery of well developed bars belonging to the Lake Dana stage, 8 miles south of Geneva, near Fayette between the Seneca and Cayuga basins. The phenomena pertaining to Lake Dana were also studied west of the Genesee valley. Positive evidence of these waters was found as far west as Akron. The drumlins throughout Genesee county are frequently cut by the wave action at this level and the detritus has been piled in short bars and spits to the leeward. Many gravel pits have been opened in these lake deposits which are practically the only source of sand and gravel over considerable territory. It now seems quite probable that further examination will connect the Lake Dana phenomena in Genesee county with the supposed Lake Dana phenomena southwest of Buffalo where the plane passes beneath Lake Erie. This will afford proof of continuous water at about 700 feet altitude all the way from the Erie basin eastward to the Cayuga valley, and the farther eastern extension is the subject of future study. While the features of Lake Dana are unequivocal they indicate a lake of relatively short life, though none the less interesting and important in revealing the glacial history of the region. Some time was spent in mapping the low level channels in the district between Leroy and Phelps. These great stream channels which extend eastward to Syracuse at levels beneath the Warren lake plane are the most puzzling features connected with the history of the glacial waters and the recession of the ice body.

Brief study was made of the Iroquois lake bottom in the northern part of western New York. In the area lying between the Genesee and Niagara rivers and the shore of Lake Ontario and the Ridge road (or beach of the glacial Lake Iroquois) we have a tract of nearly 600 square miles which is essentially prairie and forms the smoothest and most extended plain in the State. It is the famous Ontario fruit belt. East and west it is horizontal, north and south it has a fairly uniform slope to the north of about 20 feet to the mile. Over most of this belt, 8 miles wide and 75 miles long, the eye can recognize only a flat, smooth plain, the view being limited by the orchards and shade trees. The

main exceptions to the extreme flatness are low swells with a northeast-southwest direction (the direction of the glacial flow) and small sandy mounds of morainal origin. The swells or ridges are glacial drift and essentially drumlins. In Monroe county they are typical drumlins, but westward they become more and more subdued and quite disappear in Niagara county. The genesis of this remarkable plane is clear so far as its main elements are involved. The underlying rock is Medina, mostly shales but with resistant sandstone beds. The plane was developed by differential weathering in preglacial time. The invading ice sheet smoothed the rock surface by planing and filling. Subsequently the area was lake bottom under the shallow waters of Lake Iroquois, and the work of leveling and smoothing was completed by the spreading of the Iroquois sands and silts. Thus three agencies contributed to the result: atmospheric erosion served to outline the geographic features, and glacial and lake agencies to smooth it. The relative work of glacial and nonglacial agents is not closely apportioned but may be more closely determined by fuller study. The description of the "Niagara-Genesee prairie" will make an interesting chapter in the geologic evolution of the State.

Hydrology

My predecessor entered into arrangement with Mr George W. Rafter C.E. of Rochester, a distinguished hydraulic engineer and author of treatises on water supply and distribution, for the preparation of a general report on the hydrology of this State in which the subject should be treated in comprehensive form. The report was duly rendered and the printing is proceeding with adequate rapidity.

Economic geology

Louisana Purchase Exposition. The field work in this section has been largely devoted to the collection of materials intended for exhibition at the Louisiana Purchase Exposition which is specially considered under a subsequent chapter.

Marble. Aside from this H. H. Hindshaw has made a brief study of the marble quarries in and about Gouverneur, St Lawrence co., looking to the further development of these interests in that region. He has reported that in the present operations much useful material is being overlooked and there are

still marbles of good quality exposed in places where as yet no attempt has been made to utilize them.

Feldspar. Mr Hindshaw has also investigated certain localities in the search for feldspar of suitable quality for use in the manufacture of pottery and reports favorably upon a feldspar vein near Corinth, Saratoga co.

Peat. Some attention has also been paid to the peat deposits and materials gathered for future experimentation with reference to the utilization of these raw materials.

Kaolin. Some residual clays occurring near Thurman and Ticonderoga have been examined with reference to their commercial value, and the finding of such clays in the Adirondack regions is a matter of considerable scientific interest as indicating the probable escape of such deposits from the abrading action of the glaciers.

Graphite. The graphite deposits of Ticonderoga and Lake George have been examined and these examinations have served to show the presence of immense quantities of this mineral disseminated through the limestones of the Adirondacks. It is believed that processes can be devised by which this ore, not now used, can be extracted.

Iron. A visit to the iron region of Mineville showed great activity there. The opening of new mines and testing by diamond drill borings have shown the existence of an abundance of ore, and recent improvements in magnetic separation have simplified the matter of getting the ore on the market in suitable form for reduction. The increasingly large deposits of tailings from the concentrators here afford a practical field for the establishment of a cement building block industry.

Sandstone. An examination of the outcrops of the Potsdam sandstone near Fort Ann was made. This rock is here a close grained quartzite containing such a small amount of iron and other impurities that its value as ganister, glass sand and perhaps a flint for pottery purposes needs little demonstration and its existence should be made known to users of these materials. Further reference to the economic work of the department is made under the notice of the office work.

Office work

All of the field operations have necessarily involved their elaboration in the office. Consequently time has been spent by

the various officers referred to in the preparation of reports upon their work. Work that has been more strictly independent of immediate field operations is the following:

Paleontology

Faunas of Beekmantown and Chazy limestones. During several seasons past Dr Ruedemann has carried on investigations relating to the faunas of the Beekmantown and Chazy formations of the Lake Champlain basin. The elaboration of these faunas, specially the study of the Cephalopoda, has occupied much of his attention and reports relating to these subjects are in course of publication. It is well to note here that since the date of Professor Hall's account of these early Siluric faunas in 1847 little has been done to revise or bring the knowledge up to date. It was one of Professor Hall's unrealized purposes to reconsider this early work in the light of later acquisitions and we have undertaken this series of investigations in the hope of bringing together all the added knowledge of the long interval from 1847 to the present.

Graptolites. Mr Ruedemann has completed during the past year a memoir on the graptolites of the early formations which constitutes a very valuable addition to the series of publications on New York paleontology.

Type specimens. Mr Ruedemann has also had in charge the listing of the type specimens of fossils supplementary to the long list which appeared in the type catalogue published in 1903. This supplementary list is appended to this report and serves to show the importance of the additions annually made to this class of our collections.

Devonic fishes. Agreeable to an arrangement made for the study of the Devonic fishes of New York, Dr C. R. Eastman of Cambridge Mass. has carried on investigations designed to bring together all extant information upon this subject with a notice of such undescribed material as is obtainable. It has furthermore seemed of importance to consider the relations of the New York or eastern faunal province to the other geographic provinces in order that we may get light upon problems of distribution and succession. From the greater mobility of these vertebrate creatures as compared with invertebrates it may be expected that the evidence afforded by the former will be pertinent and circumstantial in indicating the direction in which migration has taken

place. This treatise involves the tabulation of all known species of fossil fishes from the region with emendation in some cases of their specific diagnoses. The species will all be illustrated and a number of forms new to science will be represented and discussed.

Fossil plants. Two years ago I entered into an arrangement with Mr David White of the United States Geological Survey for a descriptive account of the fossil plants from the rocks of New York. These interesting bodies have been, in an embarrassment of riches, not overlooked but left for a favorable opportunity for their investigation. The collections which have been brought together during the history of the Museum were acquired incidentally, but notwithstanding constitute a very extensive representation of these ancient plants. Mr White is a well known authority upon this group of organisms and he has, in pursuance of this understanding, made a careful inspection of the collections in Albany and in the intervals of his time has continued his studies upon certain parts thereof. He reports that he has given special attention to the interesting and valuable collections of Pteridophytes, beginning his investigations with the study of the Lepidophytes which it is hoped to bring together in revised form and one systematic report.

With the available opportunities for study, a cursory review of the similar material in other museums has been made; reviews of foreign literature relating to the subject brought together and much of the synonymic data is now at hand. It is hoped that the present winter will afford time for the preparation of diagnoses of all the lepidophytic species, and the publication of these in a report suitably illustrated be effected in the near future.

Devonic crinoids. In 1866 Professor Hall published a very brief account of some of the Devonic crinoids of New York based upon a remarkable discovery made in 1857 at Muttonville, now Vincent, Ontario co. The type specimens of most of this material are in the state collections but there has never been a serious effort made to elaborate the crinoids of the Devonic rocks of this State. The last half century has brought into the state collections a series of these fossils of extraordinary interest and it has been my plan for some years to prepare them for publication, as an essential addition to our knowledge of the ancient faunas of New York. This year I invited the assistance of Edwin Kirk of Columbia University, who has had some experience in

the study of the fossil Crinoidea, and during the time he was in this office good progress was made in the analysis and description of the material. The study has shown a considerable number of forms heretofore unknown to science and when all is brought together it is believed that it will embody a substantial contribution to the paleontology of New York.

Stratigraphy

The details of the stratigraphic work done in western New York during the field season of the previous year have been prepared for publication largely by D D. Luther, i. e. the determinations and explanations of the Watkins-Elmira and the Tully quadrangles.

Economic geology

Fire tests of building stones. Prof. Heinrich Ries of Ithaca has been invited to undertake a series of investigations to establish the resistance to heat of the building stones of the State. Samples of various stones have been collected from the different parts of the State, partly with the object of covering as many varieties as possible and partly to secure specimens showing a wide range of physical characters. These have been cut down to the uniform cube required for the fire test, i. e. into 3 inch cubes having smooth faces so that any slight disintegration as a result of the test can be more readily seen.

Dr Ries reports that he has in hand samples of the following well known standard construction stones: Pochuck mountain, Orange co., coarse grained granite; Garrison, fine grained granite; Peekskill, granite (used in construction of Croton dam); Nyack, trap rock; Sandy Hill, sandstone; Keeseville, gabbro; Potsdam, sandstone; Clayton, coarse grained and fine grained granite; Little Falls, sandstone and gneiss; Canajoharie, limestone; Northville, granite; Amsterdam, sandstone; Medina, sandstone; Warsaw, sandstone; Oxford, sandstone; with a few other localities not yet reported. It is proposed to test these stones at a red heat and a very dull red, the stone in each case being cooled both slowly and fast. It is furthermore proposed to heat the stones unevenly, that is so that one half of the cube will be protected while the other is heated well and a stream of water directed against this. This will tend to set up uneven stresses through the stone. In addition to the fire test proper, composition,

texture, microscopic character and density of the stone will be determined in order to ascertain what relation these bear to the fire-resisting qualties of the material.

State School of Clay-working and Ceramics. It is a source of much satisfaction to the Director to state that an understanding has been entered upon with Prof. Charles F. Binns, the Director of the New York State School of Clay-working and Ceramics, by which he will undertake to act in the capacity of expert on all questions arising in the business of this division which are germane to his specialty. Professor Binns will pass upon samples of clay submitted for examination and report and will give us his valuable assistance in all problems which may arise as to the exploitation or location of clay deposits.

Louisiana Purchase Exposition

Preparation for the exhibit of the department at the Louisiana Purchase Exposition required a considerable expenditure of time on the part of various members of the staff. The provision made for this exhibit by the state commission was so limited that it became necessary to seek the cooperation of the individual and corporate producer for some of the exhibits in economic geology. The Museum collections, although freely drawn upon, were not regarded as sufficient to meet the demands of the occasion and in seeking cooperation from other quarters the director of the scientific exhibit met with cordial response so far as the acquisition of the materials for the collection was concerned, and for its successful instalment Mr Hindshaw is largely responsible and is entitled to very great credit. The plan of the display however was conceived and directed by Dr F. J. H. Merrill, to whom acknowledgment should be made for its success as a whole. It is proper too that in this place personal acknowledgment should be tendered to the individual exhibitors who joined hands with the State in making this display as excellent as the financial situation permitted.

I append herewith a detailed classified catalogue of the exhibits and the exhibitors.

MINES BUILDING

EXHIBIT OF NEW YORK STATE MUSEUM

1 Department of geology

Maps and publications

10 geologic maps of New York State and special parts thereof
Relief map of New York

Hypsometric map of New York
Road map of New York
Publications on geology, mineralogy, topography, quarrying, mining, metallurgy, development of water resources, etc.
64 photographic enlargements illustrating New York State mineral resources and other geologic features, size 11 by 14

Metallic products

IRON ORES

Magnetic iron ores, concentrates, apatite concentrates, ores used to illustrate workings of Wetherill separator; Mineville, Witherbee, Sherman & Co.
Iron ores; Harkness, Arnold Mining Co.

LEAD AND ZINC

Zinc blende, chalcopyrite, galena, lead zinc and copper concentrates; Ellenville, Ellenville Zinc Co.

PYRITES

Pyrites, crude and concentrates; Gouverneur, Adirondack Pyrites Co.
Pyrites; Canton, High Falls Pyrites Co.

Nonmetallic products

ABRASIVES

GARNET

Garnet and garnet paper; North Creek and Minerva, H. H. Barton, Son & Co.
Garnet and garnet paper; North River, Herman Behr & Co.
Garnet; Ticonderoga, North River Garnet Co.
Garnet; Gouverneur, Gouverneur Garnet Co.

EMERY

Emery; Cortland, The Tanite Co.

MILLSTONES

Millstone; Granite, James Van Etten

INFUSORIAL EARTH

Infusorial earth; White Lead lake, Herkimer county, George W. Searles

MINERAL PAINTS

Mineral paint; Rossie, Rossie Metallic Paint Co.
Mineral paint; Roxbury, Delaware Milling, Mining & Mfg. Co.
Mineral paint; Troy, F. Thomas
Mineral paint; Ogdensburg, Wells & Hall
Mineral paint; Troy, William Conner Paint Mfg. Co.
Mineral paint; Truthville, Algonquin Red Slate Co.

GRAPHITE

Graphite; Ticonderoga, International Graphite Co.
Graphite; Ticonderoga, Joseph Dixon Crucible Co.
Graphite; Ticonderoga, Ticonderoga Graphite Co.

TALC

Talc; Gouverneur, International Pulp Co.
Talc; Gouverneur, Ontario Talc Co.

Talc; Gouverneur, Union Talc Co.
Talc; Gouverneur, United States Talc Co.

MICA

Mica; Bachellerville, Adelbert Gordon

SALT

Salt; Silver Springs, Worcester Salt Co.
Salt; Pifford, Genesee Salt Co.
Salt; Ithaca and Warsaw, National Salt Co.
Salt; Syracuse, Remington Salt Co.
Salt; Watkins, Union Salt Co.
Salt; Watkins, Watkins Salt Co.
Salt; Leroy, Empire State Salt Co.
Rock salt; Retsof and Livonia, Retsof Mining Co.
Solar salt; Syracuse, Onondaga Coarse Salt Association

INDIVIDUAL EXHIBITOR

Solvay Process Co., Syracuse, chemicals derived from salt, processes of manufacture

GYPSUM

Gypsum; Wheatland, Consolidated Wheatland Plaster Co.
Gypsum; Oakfield, Oakfield Plaster Mfg. Co.
Crude gypsum; Fayetteville, National Wall Plaster Co.
Gypsum; crude and manufactured, also photographs; Oakfield, United States Gypsum Co.

PLASTER OF PARIS

Plaster of paris; Port Gibson, Ezra Grinnell
Plaster of paris; Fayetteville, National Wall Plaster Co.
Statuary of plaster of paris; Oakfield, United States Gypsum Co.

LAND PLASTER

Land plaster; Wheatland, Consolidated Wheatland Plaster Co.
Land plaster; Fayetteville, National Wall Plaster Co.
Land plaster; Port Gibson, Geo. Grinnell

PETROLEUM

Collated by J. S. Bellamy, Wellsville N. Y.

Crude oil; Andover, Atwood & McEwen
Crude oil; Willing, Empire Gas & Fuel Co., Ltd.
Crude oil; Scio, Franchot Bros.
Crude oil; Wellsville, Church & Co.
Crude oil; Wellsville, James McEwen
Crude oil; Allegany, Rudolph & Dotterwich
Crude oil; Rexville, Grumley Oil Co.
Crude oil; Alma, Vossler Bros. & Quick
Crude oil; Alma, Church & Bradley
Crude oil; Andover, Mutual Gas Co.
Crude oil; Alma, Alps Oil Co.
Crude oil; West Union, Clark, Tracey & Co.
Crude oil; Alma, James Thornton Estate

Crude oil; Whitesville, M. Mervine
Crude oil; Alma, C. R. Scott
Crude oil; Scio, Bellamy & Elliott
Crude oil; Scio, Applebee & Baldwin
Crude oil; Alma, Quick & Co.
Crude oil; South Bolivar, Scott, Fuller & Fay
Crude oil; South Alma, C. M. Wyvell
Crude oil; Wellsville, Shannon Oil Co.
Crude oil; Andover, Hunt farm
Crude oil; Scio, from first oil well in Allegany co.
Crude oil; Wellsville, Empire Gas & Fuel Co., L't'd
Oil sand and crude oil; Genesee, J. B. Gray
Oil sand and crude oil; Bolivar, Vosburg Oil Co.
Oil sand and crude oil; Scio, Scio Oil & Gas Co.
34 bottles refined products; Wellsville, Wellsville Refining Co.

Building stones

GRANITE

Granite, 10 inch cube; Grindstone Island, R. Forsyth
Granite, 10 inch cube; Garrisons, A. Gracie King
Granite, 10 inch cube; Ossining, Francis Larkins
Granite, 10 inch cube; Mount Eve, Mount Eve Granite Co.
Granite, 10 inch cube; Cortland, E. P. Roberts
Granite, 10 inch cube; Saratoga Springs, L. H. White

DIABASE

Diabase, 10 inch cube; Staten Island, Frank Bennett

NORITE

Norite, 10 inch cube; Keeseville, B. B. Mason

SANDSTONE

Red sandstone (Catskill), 10 inch cube; Roxbury, A. F. Bouton
Sandstone, 10 inch cube; Medina, Horan Brothers
Sandstone (Medina), 10 inch cube; Lewiston, L. H. Hotchkiss
Sandstone, 10 inch cube; Potsdam, D. Parmeter
Sandstone, 10 inch cube; Potsdam, Potsdam Sandstone Co.
Sandstone, 10 inch cube; Schenectady, A. Shear & Co.

INDIVIDUAL EXHIBITOR

Medina Quarry Co., Medina, walls showing various styles of finish and carving; red and white tiling

BLUESTONE

Bluestone, 10 inch cube; Rondout, H. Boice & Co.
Bluestone, 10 inch cube; Saugerties, Burhans & Brainard
Bluestone, 10 inch cube; Belvidere, Albert Dibble
Bluestone, 10 inch cube; Lordville, J. F. Kilgour
Bluestone, 10 inch cube; Ithaca, G. J. McClune
Bluestone, 10 inch cube; Walton, James Nevins & Son
Bluestone, 10 inch cube; Portageville, Peter Pitkin's Sons
Bluestone, 10 inch cube; Elmira, A. D. Symonds
Bluestone, 10 inch cube; Rock Glen, Warsaw Bluestone Co.

INDIVIDUAL EXHIBITOR

Hudson River Bluestone Co., Ulster county, 10 inch cubes bluestone, flags, tiling, ashler

LIMESTONE

Limestone (Trenton), 10 inch cube; Three Mile Bay, J. J. Barron
Limestone, 10 inch cube; Hudson, J. B. Berridge
Limestone (Lower Helderberg), 10 inch cube; New Baltimore, Eugene Campbell
Limestone (Niagara), 10 inch cube; Lockport, B. & J. Carpenter
Limestone, 10 inch cube; Rochester, Foerly & Kastner
Limestone (Trenton), 10 inch cube; Chaumont, Duford & Son
Limesone (Corniferous), 10 inch cube; Buffalo, D. R. & H. Fogelsonger
Limestone, 10 inch cube; Leroy, Morris & Strobel
Limestone (Trenton), 10 inch cube; Glens Falls, Glens Falls Co.
Limestone (Calciferous), 10 inch cube; Amsterdam, D. C. Hewitt
Limestone, 10 inch cube; Cobleskill, W. Rielly
Limestone, 10 inch cube; Tribes Hill, J. Shanahan
Limestone, 10 inch cube; Prospect, Evan T. Thomas
Limestone, 10 inch cube; Prospect, R. Jones

MARBLE

Marble, 10 inch cube; Gouverneur, Milo M. Belding
Marble, 10 inch cube; Canton, Canton Marble Quarry
Marble, 10 inch cube; Gouverneur, Empire Marble Co.
Marble, 10 inch cube; Gouverneur, Extra Dark Marble Co.
Marble, 10 inch cube; Tuckahoe, Masterton & Hall
Marble, 10 inch cube; Waterloo, Loren Thomas
Marble, 10 inch cube; Gouverneur, Northern New York Marble Co.
Marble, 10 inch cube; Pleasantville, A. L. Pritchard
Marble, 10 inch cube; Gouverneur, St Lawrence Marble Co.
Marble, 10 inch cube; Gouverneur, D. G. Scholten
Marble, 10 inch cube; South Dover, South Dover Marble Co.
Marble, 10 inch cube; Gouverneur, Gouverneur Marble Co.
Marble ashlers; Gouverneur, White Crystal Marble Co.

SLATE

INDIVIDUAL EXHIBITOR

H. H. Mathews Consolidated Slate Co., Washington county, N. Y., unfading red, green and purple roofing slates, tiling, slabs, stair treads and risers. Red slate mantel.

CEMENT

INDIVIDUAL EXHIBITOR

Helderberg Cement Co.; Howes Cave, cement, cement materials, processes of manufacture

MARL

Marl; Wayland, T. Millin
Marl; Wayland, Wayland Portland Cement Co.
Marl; Warners, Empire Portland Cement Co.

Clay products

TILE

Tile; Rochester, Rochester Brick & Tile Co.
Drain tile; Warners, Onondaga Vitrified Brick Co.

TERRA COTTA

Terra cotta; Kreischerville, Kreischer & Sons

SPECIAL EXHIBIT OF CLAY PRODUCTS

Collated by Prof. Charles F. Binns

New York State School of Clay-working & Ceramics, Alfred, N. Y.

BRICK

Brick; Alfred Station, Alfred Clay Co.
Brick; Attica, Attica Brick & Tile Co.
Brick; Corning, Corning Brick, Tile & Terra Cotta Co.
Brick; Horseheads, Horseheads Brick Co.
Brick; Ithaca, Interstate Conduit & Brick Co.
Brick; Jamestown, Jamestown Shale Paving Brick Co.
Brick; Jewettville, Jewettville Pressed Brick & Paving Brick Co.
Brick; Lancaster, J. H. McCutcheon
Brick; Olean, J. C. & A. McMurray
Brick; Canandaigua, New York Hydraulic Pressed Brick Co.
Brick; Buffalo, Queen City Brick Co.
Brick; Rochester, Rochester Brick & Tile Co.
Brick; Tonawanda, Tonawanda Brick Co.

TILE

Tile; Alfred Station, Alfred Clay Co.
Tile roofs; Alfred, Celadon Roofing Tile Co.

POTTERY

Pottery; Alfred, New York State School of Clay-working and Ceramics

INSULATORS

Insulators; Brooklyn, Empire China Works
Insulators; Syracuse, Pass & Seymour

INDIVIDUAL EXHIBITOR

General Electric Co., Schenectady, insulators

FELDSPAR

Feldspar; Batchellerville, Adelbert Gordon
Feldspar; Bedford, P. H. Kinkel

QUARTZ

Quartz; Bedford, P. H. Kinkel

SAND

Sand; Northport, Williamson & Co.
Sand; Croton Landing, W. B. Underhill Brick Co.

Special exhibits

INDIVIDUAL EXHIBITOR

Wetherill Separating Co., New York city, Wetherill magnetic separator, type E, no. 3, working on New York magnetic iron ores

Robins Conveying Belt Co., New York city, belts and conveyor on separator

Rowand Expansion Pulley Co., Denver, Col., pulleys on separator

2 Department of paleontology

The publications of this department on the subject of the paleontology of the State of New York consisting of 35 volumes, 1847-1904. This series of publications received the grand prize at the Paris Exposition of 1900 and the gold medal at the Pan-American Exposition in 1901.

Slab of Potsdam sandstone representing a portion of the primordial or Cambric beach laid down about the shores of the Adirondack continental nucleus. This slab bears the trails of what is believed to have been a simple primitive type of mollusk which dragged itself back and forth over the beach at the ebb of the tide. Taken from Bidwell's Crossing, Clinton co., N. Y.

Stratigraphic and paleontologic maps, original drawings and lithographs

Restoration in plaster of paris showing the structure of the fossil crustaceans Eurypterus and Hughmilleria

As the awards made to this exhibit by the juries of the Louisiana Purchase Exposition have been announced as this report is undergoing preparation it seems appropriate to notice them in this connection. They are as follows:

Grand prize for the Museum exhibit in the Education Department

Grand prize general exhibit in paleontology, including paleontologic publications, slab of Potsdam sandstone with trails, restoration of fossils, original drawings and lithographs

Grand prize: salt products, Solvay Process Co.

Grand prize: gypsum, United States Gypsum Co.

Gold medal: general scientific publications of the Museum

Gold medal: minerals and building stones, Museum exhibit

Gold medal: cement, Helderberg Cement Co.

Gold medal: slate, Mathews Consolidated Slate Co.

Gold medal: iron ore separator, Wetherill Separating Co.

Gold medal: electric insulators, General Electric Co.

Silver medal: salt, Empire State Salt Co.

Silver medal: salt, Onondaga Coarse Salt Association

Silver medal: salt, National Salt Co.

Silver medal: salt, Worcester Salt Co.

Silver medal: sandstone, Medina Quarry Co.

Silver medal: sandstone, Hudson River Bluestone Co.

Silver medal: collective exhibit

Silver medal: geologic maps

Silver medal: garnet, Herman Behr & Co.

Silver medal: iron ore, Witherbee, Sherman & Co.

Silver medal: clay products, N. Y. State School of Clay-working and Ceramics

Bronze medal: marble, D. G. Scholten
Bronze medal: iron ore, Arnold Mining Co.
Bronze medal: plaster model, Tilly Foster Iron Mine

MINERALOGY

The mineralogist has been concerned with increasing the representative collection of the minerals from the State. Of such material specially notable additions have been received from the cement mines of Rondout. These New York minerals present a series of interesting problems relating to mineral genesis with the study of which the mineralogist has been a good deal engaged. The collection of New York State minerals at present constitutes over 600 specimens and contains much material of high scientific interest.

BOTANY

The work of the botanic department of the State Museum may be classified as office work and field work. The former is chiefly done during the winter, the late fall and early spring months; the latter during the rest of the year. The first three months of the fiscal year beginning Oct. 1 and ending Sep. 30 were chiefly devoted to the study and examination of the specimens of plants collected and contributed during the five months immediately preceding Oct. 1, 1903, and in the preparation of the annual report of the botanist for that year. The winter and early spring were devoted to the mounting of specimens, placing some in trays for table case exhibition, others in small pasteboard boxes for better protection against the attacks of insects, and adjusting them to their proper places in the herbarium cases, suitable labels having in all cases been placed with the specimens. Some time was given to the examination and determination of specimens sent for that purpose by correspondents, many of those which had come during the collecting season being reserved for a more convenient occasion for their examination.

Field work has been done in 16 counties of the State. The collection of specimens of fungi of the various orders and the investigation of our mushroom flora have been continued as opportunity occurred. The result has been the addition of a few species of edible mushrooms to our already long list of 150 species figured on 86 plates.

Continued and special attention has been given to the study and collection of specimens of our species of Crataegus. Large

collections of many species new to the herbarium have been secured. In most cases the species are represented by both flowering and fruiting specimens.

The services of Mr Stewart H. Burnham, as temporary assistant, were secured from July 1 to Sep. 21. He was employed in making a general rearrangement of the books and pamphlets of the library and of the duplicates and extralimital specimens of the herbarium, and in other general museum duties.

ENTOMOLOGY

Mosquitos. The state entomologist reports that the season of 1904 has been comparatively free from insect injury to agricultural crops and consequently he has given considerable time to investigating our mosquito fauna. Over 50 species have been found in the State, and the results of this work have been embodied in a bulletin, illustrated by over 300 original drawings or photomicrographs, giving the life history and describing the immature stages of over 40 species and characterizing 12 as new.

San José scale. The investigations of methods for controlling the San José scale, Aspidiotus perniciosus Comst., have been continued and a number of experiments with various washes conducted in a scale-infested orchard at Warwick with gratifying results. The efficacy of natural enemies in controlling this serious pest, has been further tested by liberating a third instalment of beneficial Chinese lady beetles, Chilocorus similis Rossi, in an infested orchard at Kinderhook.

Grape root worm. The work of 1902-3 on the grape root worm, Fidia viticida Walsh, in Chautauqua county vineyards, has been continued and valuable data as to the efficacy of arsenical poisons for the control of this species, secured.

Aquatic insects. Investigations of aquatic insects, started in 1900, have been continued and Dr James G. Needham of Lake Forest University, is engaged upon a monographic account of our stone flies or Plecoptera.

Leaf-hoppers. The office has been fortunate in securing Prof. Herbert Osborn of Columbus O., a well known specialist on leaf-hoppers or Jassidae, to do some special collecting in the State and the result of his work will be given in detail in his report.

Hemiptera. Mr E. P. Van Duzee of Buffalo, a skilful collector and well known authority on Hemiptera, has also collected in the

Adirondacks and Catskills. The value of this work is greatly enhanced by his annotated catalogue reproduced in the report of the entomologist.

Publications. The entomologist has made numerous contributions of a practical nature to the agricultural press and one of his more extensive papers (aside from bulletins issued by the Museum), on "Insects Injurious to Pine and Oaks," published in the 7th Report of the Forest, Fish and Game Commission, was issued during the year. Two timely bulletins, that on the *Grapevine Root Worm,* Museum bulletin 72, and the *Monograph of the Genus Saperda,* Museum bulletin 74 (by the entomologist and L. H. Joutel of New York), were issued during the year, in addition to the 19th Report of the State Entomologist (Museum bulletin 76). There is in press a monographic account of the May Flies and Midges of New York by Messrs Needham and Johannsen, and a memoir on Park and Woodland Tree Insects is ready for press.

Louisana Purchase Exposition. The office supervised the preparation of a collection of insects, which was exhibited at the Louisiana Purchase Exposition by the Forest, Fish and Game Commission. It comprised about 250 species, the life history and habits of 140 being represented in greater or less detail.

ADDITIONS

The additions to the state collections have been large and particularly valuable because of the excellent series of mosquitos, principally bred forms, the result of the summer's work. The usefulness of this collection is greatly enhanced by the preparation of over 600 microscopic slides showing the minute structure of the different species and also by over 200 photomicrographs made from these mounts. This mounted and photographed material constitutes a permanent collection which will be of much value in future studies of this economically important and interesting group.

The routine work of the office has been conducted as usual, and the public interest in this branch of science is manifest by the constantly increasing correspondence. The reports of voluntary observers, the list of publications and of contributions to the state collections, contained in the entomologist's report, are records of these activities of the office.

ZOOLOGY

The time of the zoologist has been given largely to the care of the collections and the special study and increase of the series of Myriopods and Phalangida of the State which have heretofore received little attention. The zoologist has also prepared a Catalogue of the Higher Crustacea of New York City, which involved the identification of the forms collected during the preceding two summers. This is now in press as a bulletin of the Museum.

It has been necessary to replace many of the specimens of birds, and new material of these has been acquired during the open season and also material for mounted groups of birds with their nests and surroundings. Two of these groups, the long-billed marsh wren Pelmatodytes palustris (Wils.) and red-wing blackbird Agelaius phoeniceus (Linn.) have already been set up by the taxidermist, and they form an attractive and interesting exhibit of the most approved and effective methods of displaying these objects.

Birds. Mr E. H. Eaton has been engaged in revising the migration schedules of birds and collating material and notes necessary for the Museum publication relating to the species and distribution of the birds of this State. Mr Eaton's publication will be a summary of what has been done in New York ornithology, will plot the migration schedules and it is expected also will cover a description and illustration of all the birds of our avifauna.

ARCHEOLOGY

The work done by Dr William M. Beauchamp in this section is largely the preparation of bulletins for publication. These include the *History of the New York Iroquois,* which is now essentially printed and progress has been made on a bulletin covering the Civil, Religious and Mourning Councils and Ceremonies of Adoption, also one on Indian Place Names in New York. Some additions of value have been made to the collections so far as the meager appropriations therefor permit and these are separately specified in the accession list.

PUBLICATIONS

The publications of the year are as follows:

Annual reports

1 56th Report of the State Museum for the fiscal year ending Sep. 30, 1902, v. 1. 473 p.

2 22d Report of the State Geologist for the fiscal year ending Sep. 30, 1902. 140 p.

Memoirs

3 No. 6, Naples Fauna in Western New York. 268 p. 26 pl.

Bulletins

Mineralogy

4 No. 70, List of New York Mineral Localities. 110 p.

Paleontology

5 No. 63, Stratigraphic and Paleontologic Map of the Canandaigua and Naples Quadrangles. 78 p.

6 No. 69, Report of the State Paleontologist for the fiscal year ending Sep. 30, 1902. 464 p. 52 pl.

Entomology

7 No. 72, Grapevine Root Worm. 58 p. 13 pl.

8 No. 74, Monograph of the Genus Saperda. 88 p. 14 pl.

9 No. 76, 19th Annual Report of the State Entomologist on the Injurious and other Insects of the State of New York for the fiscal year ending Sep. 30, 1903. 150 p. 5 pl.

Botany

10 No. 75, Report of the State Botanist for the fiscal year ending Sep. 30, 1903. 70 p. 4 pl.

Archeology

11 No. 73, Metallic Ornaments of the New York Indians. 122 p. 37 pl.

Handbooks

12 University handbook 6, Pt 3, List of State Museum Publications. 26 p.

13 No. 17, Economic Geology of New York. 44 p.

Circulars

14 Description of the Geologic Map of the Canandaigua-Naples Quadrangles. 32 p.

THE MUSEUM COLLECTIONS; THEIR CONDITION AND DISTRIBUTION

It is hardly necessary for me to refer to the fact that the scientific collections of the State Museum are extensive and valuable. The interested public is aware that nowhere else is to be found a collection of the natural products of the State so extensive and exhaustive, and its value to the students of science and as a factor in scientific knowledge is momentous.

The condition of these collections continues to be, as it has been for many years past, very unsatisfactory. More than 20 years ago the Legislature of the State, convinced that the Museum had filled the Geological Hall to repletion, provided the State Hall for the reception of the overflow, but we failed to acquire the State Hall except in small part. We find therefore today the scientific collections of the State partly in the old rooms of the Geological Hall, crowding all cases and drawers and filling all available nooks and corners; in the State Hall are upward of 5000 drawers of paleontologic specimens and several hundred boxes in the rooms in the basement. The corridors and landings of the fourth floor at the west end of the Capitol contain a part of the very valuable and unique collection of Indian relics, and the basement of the Geological Hall and the storerooms of the Capitol and malthouse hold large quantities of material which it has been necessary to pack away. One unique specimen weighing upward of 20 tons is stored with the Flint Granite Company at Cemetery station. Under such conditions the public is practically debarred from access to the scientific collections of the State. Even the exhibition rooms of Geological Hall with the exception of the mineral room on the first floor and the zoologic exhibit on the fourth floor are badly illuminated and extremely unattractive.

The facilities for display are archaic. We do not even know our own resources. There are boxes of scientific specimens in our storage quarters which have not been opened in half a century, although for the most part we have a careful inventory of everything that has been sealed up and put in storage in recent years.

A considerable part of the room on the second floor of Geological Hall, formerly used for the exhibition of collections, has been taken for needed office quarters.

In the State Hall no attempt is made to display any of the material. The rooms are with one exception badly lighted so that

the illumination is even unsatisfactory for the ordinary duties of the office staff.

The condition of our quarters has not materially changed in many years. We recognize this and have become in a measure used to the discomfort of doing work in unfavorable surroundings and with poor light; but we can not fail also to recognize the fact that with the large annual acquisitions to all the collections the condition does not remain the same as it has been but grows worse each year. In the department of paleontology alone our annual acquisitions have averaged during the past six years about 10,000 specimens. These are ponderable additions which can not be tucked away into inconsiderable space, and we find it necessary in the elaboration of our scientific work to unpack such material long enough for the necessary examination and then to repack it and store it away. We do not work at an advantage. There is a needless expenditure of time and energy and solicitude in being unable to have access to the material as it is wanted. There is danger of inaccuracy in work or incompleteness of observation on account of the labor involved in making the needed material accessible just at the time it is wanted. What is true of this section is in somewhat less degree true of the others. We have long since outgrown our quarters, and our collections are now squeezing us, not merely to the inconvenience of our work, but to its injury and probable imperfection. We realize however that there is no hope of remedy for this condition till circumstances make it practicable to instal these collections and our offices in a suitable building. The most urgent need of the Museum at this date is room for the accommodation and display of its collections, and for the adequate equipment of its offices.

APPENDIX 1

Accessions

The additions to the collections have been by donation, exchange, purchase and collection. A detailed statement of these acquisitions is given herewith.

Geology

DONATION

German World's Fair Commission to the St Louis Exposition. Machine made peat and peat charcoal, Germany 20

COLLECTION

Assistant in Geology. Albany. Poughquag quartzite; gneisses near contact of quartzite; iron ores and associated rocks, Dutchess county 52

Set of specimens from pegmatite vein, feldspar, garnet and mica from 2 miles west of Corinth	20
Set of rock specimens from dikes in Syracuse and East Syracuse	20
Collection of rocks from Gouverneur, St Lawrence co.	18
1 large nodule from Marcellus shale, north of Cedarvale, Onondaga co.	1
Graphite ore and rock specimens from Fort Ann and Comstocks, Washington co.	40
Graphite, residual clay, limestone and dike rocks from Ticonderoga, Essex co.	15
Rocks and minerals from Mineville	12
Tremolite, Peabody Bridge, St Lawrence co.	4
Cream colored marble near Peabody Bridge, St Lawrence co.	1
Celestite, Severance Quarry, Fayetteville	10
Limestone, Severance Quarry, Fayetteville	1
Sandstone dike, Split Rock Quarry, Syracuse	1
Orthoclase, chlorite and muscovite, Batchellerville	1
Feldspar, Batchellerville	2
Breccia, Batchellerville	2
Orthoclase, Corinth	2
Biotite, Corinth	1
Garnet, Corinth	1
Graphite, Daggett Pond, Warren co.	4
Garnet, Daggett Pond, Warren co	1
Graphitic limestone, near Crowfoot Pond, town of Moriah, Essex co	3
Siderite, Amenia	1
Total	233

A number of specimens of rocks and ores have been sent in for identification, some of which may be preserved for Museum purposes.

Paleontology

DONATION

Simms, Joseph. New York. Coal Measure fossils from Mazon creek, Illinois	92
Wilson, John D. Syracuse. Agoniatite limestone fossils, Onondaga Hill	3
Davis, E. E. Norwich. Crustaceans from the Ithaca beds, Swartwood, Chemung co.	2
Griswold, J. N. Amsterdam. Trenton limestone near Amsterdam	1
Hudson, G. H. Plattsburg. Chazy limestone fossils from Valcour Island	12

EXCHANGE

Morse, E. V. Lorain O. Onondaga limestone fossils from Ohio	68

COLLECTION

The Director. Fossils from the Devonic and Siluric from Percé, Gaspé basin and Grande Grève, Quebec	625
Luther, D. D. Fossils from the Cashaqua shale, Penn Yan	30

Mattimore, H. S. Fossils from the Rondout beds, Litchfield........ 58
Hartnagel, C. A. Fossils from the Chemung beds, Hornellsville.... 150
Fossils from the Guelph dolomite, Niagara Falls, Canadian side... 150
Kugel, Carl. Fossils from the Guelph dolomite, Niagara Falls, Canadian side.. 289
Braun, Frederick. Slab of fossil trails, Potsdam sandstone, Bidwells crossing Clinton co.. 1
Fossils from the Pittsford shale, "Spring House" farm, 2 miles north of Pittsford, Monroe co.. 30
Goldman, Marcus I. Fossils from the Black river and Trenton limestones, Watertown, Lowville and vicinity, St Lawrence co........ 506

Total..2288

Mineralogy

DONATION

Clough, H. O. Albany. Dolomite, Indian Ladder, Albany county... 1
Stilwell, L. W. Deadwood S. D. Gypsum (selenite) Camillus N. Y. 1
Colvin, Verplanck. Albany. Oligoclase, Essex county............ 1
Garvey, Matt. Ticonderoga. Titanite, Towner hill, Ticonderoga.... 1
King, *Mr.* East Chatham. Barite near Canaan.................... 1
Day, *Dr* **David T.** U. S. Geol. Sur. Asphaltum "manjak", Barbadoes 1
Peck, H. C. Menands. Calcite, Cumberland, England............. 1
Clark, P. E. Rondout. Dolomite, Rondout, Ulster co............... 17
Quartz, Rondout, Ulster co.. 164
Calcite, Rondout, Ulster co....................................... 187
Calcite (large specimens), Rondout, Ulster co..................... 13
Pyrite, Rondout, Ulster co.. 112
Pyrite (dendritic), Rondout, Ulster co............................ 5
Marcasite, Rondout, Ulster co..................................... 6
Ellenville Zinc Co. Ellenville. Galena (large crystal), Ellenville..... 1
Chalcopyrite in quartz, Ellenville................................ 15

EXCHANGE

Magill, C. N. Albany. Geodes lined with chalcedony and crystallized quartz, Plymouth Ill.. 6
Geodes lined with quartz and calcite, Keokuk Ia.............. 4
Geodes lined with calcite, Cedar Creek Ill.................... 6
Geodes lined with quartz, pyrite and rutile, Hamilton Ill...... 5
Geodes lined with calcite and siderite, Siloam Springs Ill........ 15
Pfordte, Otto F. Rutherford N. J. Limonite geodes filled with sand, Sayville N. J.. 4
Limonite pseudomorphs after pyrite, Wrightsville Pa............ 27
Hardystonite and franklinite, Franklin N. J...................... 1
Paramalaconite, Bisbee Ariz...................................... 1
Argentite (crystal), Sonora Mex.................................. 1
Spodumene, Etta Mine S. D.. 1
Thaumasite, West Paterson N. J................................... 1
Pyrite, Sayville N. J... 3

Roeblingite in bementite, Franklin N. J. 1
Wulfenite, Sonora Mex. 1

Manley, John A. New Brunswick N. J. Pyrrhotite, Franklin Furnace N. J. 1
Hancockite, Franklin Furnace N. J. 1
Leucophoenicite, Franklin Furnace N. J. 1
Caswellite, Franklin Furnace N. J. 1

PURCHASE

Clark, P. E. Rondout. Quartz, Rondout N. Y. 46
Marcasite, Rondout N. Y. 7
Pyrite, Rondout N. Y. 18
Pyrite (dendrite), Rondout N. Y. 1
Dolomite, Rondout N. Y. 3
Anthracite in calcite, Rondout N. Y. 1
Brookite in quartz, Ellenville N. Y. 1

Haskins, *Mr.* Round Lake. Quartz (crystals), Saratoga N. Y. 46
Quartz (grouping), Saratoga N. Y. 3
Calcite, Saratoga N. Y. 5
Gypsum, Hudson N. Y. 17

Foote Mineral Co. Philadelphia Pa.
Crocoite (group), Tasmania 1
Fayalite, Rockport Mass 1
Calcite, Cumberland, Eng. 1
Rensselaerite, Diana 1

COLLECTION

The Mineralogist
Calcite, Coeymans N. Y. 12
Smithsonite on sphalerite, Flat Brook 3
Galena in quartz, Flat Brook 4
Galena (massive), Flat Brook 1
Sphalerite, Flat Brook 2
Calamine and smithsonite in sphalerite, Flat Brook 1
Greenockite (?) in sphalerite, Flat Brook 1
Clinochlore on dolomite, Ossining 3
Sphalerite on dolomite " 2
Pyrite on dolomite, " 2
Amphibole (tremolite), " 4
Talc on dolomite, " 2
Dolomite, " 3
Calcite, Glens Falls 10
Gypsum, Fayetteville 1
Calcite on limestone, Hudson 3
Barite and calcite on limestone, Hudson 1
Quartz, Hudson N. Y. 4

The Assistant in Geology
Beryl, Hope, Saratoga co. 1
Quartz (rose), Hope, Saratoga co. 1
Margarite in microcline, 2 miles north Batchellerville, Saratoga co. 1

Orthoclase, 2 miles north Batchellerville, Saratoga co............ 2
Wernerite, 2 miles north Batchellerville, Saratoga co.............. 1

Total.. 825

Zoology

DONATION

Mammals

Merritt, *Mrs* **M. I.** Oak Knoll, Albany co. Nest of red squirrel, Sciurus hudsonicus 1
Hall, C. K. East Schodack. Weasel, Putorius noveboracensis; Red fox, Vulpes fulvus, young.................... 2
Heiser, Harold. Albany. Brown bat, Myotis lucifugus..... 1

Aves

Seymour, M. Albany. Flicker, Colaptes auritus........... 1
Smith, S. B. East Chatham. Screech owl, Megascops asio.. 1
Lawrence, E. C. Quoque. Humming bird, Trochilus colubris, nest.. 1
Hall, C. K. East Schodack. Snowflakes, Passerina nivalis; crow, Corvus americanus; sharp-shinned hawk, Accipiter velox; redstart, Setophaga ruticilla, nest and eggs; barn swallow, Hirundo erythrogaster, nest and eggs 8

Reptiles

Halpin, M. New York city. Spotted turtle, Chelopus guttatus 1
Hall, C. K. East Schodack. Mud turtle, Aramochelys odorata; wood tortoise, Chelopus insculptus............. 2
Van Slyke, Bronk. Aquetuck. Black snake, Bascanion constrictor 1
Klein, E. N. E. College Point. Garter snake, Eutaenia sirtalis ordinata.. 1
Lindsey, M. E. Spearville Ga. Chameleon, Sceloporus sp.. 1

Pisces

Treadwell, *Prof.* **A. L.** Poughkeepsie. Millers thumb, Boleosoma nigrum olmstedi...................................... 1
Forest, Fish and Game Commission. Albany. Lake trout, Christivomer namaycush, abnormal, from Owasco lake; smelt, Osmerus mordax, from Little Clear lake................ 2

Invertebrates

Bradt, S. C. Albany. Window spider, Epeira insularis....... 1
Shepard, J. B. Syracuse. Myriopoda, Octocryptops sex spinosus and Linotaenia fulva......................... 10

Total..2240

The accessions by collection consisted of 205 specimens of birds, representing 76 species. Some 2000 specimens of Myriopoda were taken, of about 25 species and a large number of Phalangida and Araneida, which have not yet been identified.

Archeology

DONATION

Seton-Karr, H. W. London, England, through the United States National Museum. Chipped flint implements from the Fayoom district, Egypt 119

PURCHASE

Dailey, W. N. P. Amsterdam. A string of copper and shell beads with gorget attached, from an Indian grave at Athens N. Y... 1

Burgess, Mary E. Gorham. Indian skeletons.......... 2

Reed, W. F. L. F. Smiths Mills. An ancient French (?) sword hilt, found in excavating in the Seneca reservation near Smiths Mills.. 1

J. R. Nissley. Ada O.

1 parallel edged gorget, Wyandot county, O.
1 unfinished canoe-shaped gorget, Coweta county, Ga.
1 gorget with projections, Crawford county, O.
1 thick gorget, Hancock county, O.
1 "knob back" gorget, Adams county, Ind.
1 "knob back" gorget, Mercer county, O.
1 small green gorget, Prebel county, O.
1 banner stone of striped slate, Darke county, O.
1 banner stone, Boone county, Ind.
1 straight and cylindric banner stone, Boone county, Ind.
1 banner stone, expanding sides, Hillsdale Mich.
1 butterfly form of banner stone, Hillsdale county, Mich.
1 deeply notched banner stone, Washington county, Mich.
1 crescent-shaped banner stone, Hancock county, O.
1 large crescent banner stone, Wyandot county, O.
1 diamond-formed banner stone, Randolph county, Ind.
1 one sided banner stone, Washtenaw county, Mich.
1 crescent banner stone with terminal knobs, Fowlerville Mich.
1 crescent banner stone with lateral perforation, Hillsdale county, Mich.
1 butterfly banner stone, Van Wert county, O.
1 bird amulet with projecting eyes, Hillsdale county, Mich.
1 banded bird amulet, Boone county, Ind.
1 bar amulet (?) Putnam county, O.
1 bar amulet of striped slate, Hillsdale county, Mich.
1 thick amulet, near Ada O.
1 large pendant of chocolate colored slate, Auglaize county, O.
1 striped slate pendant, no locality
1 brown slate pendant, Paulding county, O.
1 pendant with expanded end, Allen county, O.
1 pendant with expanded end, Auglaize county, O.
1 green slate pendant, Mercer county, O.
1 green slate pendant, Wyandot county, O.

1 red slate pendant, Wyandot county, O.
1 striped slate pendant, Prebel county, O.
1 cone of green stone, Randolph county, Ind.
1 grooved cone, Union county, O.
1 bead or ornament of granite, grooved, Richland county, O.
1 grooved clay bead, Hightower river, Bartow county, Ga.
1 grooved slate bead, Paulding county, O.
1 flattened elliptic bead, Ann Arbor Mich.
1 ceremonial bead, Wyandot county, O.
1 green slate chisel, Paulding county, O.
1 granite chisel, rounded, Adams county, Ind.
1 white flint chisel, 5⅜ inches, Franklin county, Mo.
1 white flint chisel, Cooper county, Mo.
1 granite chisel, Miami county, O.
1 double edged chisel, Columbia county, Wis.
1 grooved ax, Sanilac county, Mich.
1 ax with broad edge, near La Grande Ind.
3 cliff dwellers axes, Gila river, Arizona
1 cliff dwellers ax, Arizona
1 grooved ax, Cooper county, Mo.
1 small grooved ax, Crawford county, O.
1 local type of grooved ax, Cooper county, Mo.
1 white flint spade, Columbia county, Wis.
1 notched hoe, 9½ inches long, Johnson county, Ill.
1 deeply notched hoe, Shelby county, O.
1 white flint hoe, Jackson county, Ill.
1 sickle-shaped knife, Union county, O.
1 bluish flint spear, serrated, Union county, O.
1 yellow jasper spear, Johnson county, Ill.
1 barrel-shaped perforated stone, Smoky mountain, Tenn.
1 striped slate tube, 7 inches long, Mercer county, O.
1 perforated article of brown quartz, no locality
1 brown slate tube, 5½ inches long, Prebel county, O.
1 perforated globular stone, Brown county, Ind.
1 boat stone of striped slate, Shelby county, O.
1 elliptic bone awl, Ann Arbor Mich.
1 small grooved war club, Darke county, O.
1 cliff dwellers pitcher, Phoenix Ariz.
1 cliff dwellers vessel, Ann Arbor Mich.
1 cliff dwellers cup (cemented), Gila river, Arizona

Total.. 197

Botany

PLANTS ADDED TO THE HERBARIUM

New to the herbarium

Amanita radicata *Pk.*
A. lignophila *Atk.*
A. crenulata *Pk.*
Arenaria leptoclados *Guss.*
Arisaema stewardsoni *Britton*
Boletus atkinsonii *Pk.*
B. laricinus *Berk.*
B. nobilis *Pk.*
B. rugosiceps *Pk.*
Botrychium tenebrosum *A. A. Eaton*
Bryum pendulum *Schp.*
Clavaria botrytoides *Pk.*
C. xanthosperma *Pk.*
Collybia amabilipes *Pk.*
Convolvulus repens *L.*
Cortinarius heliotropicus *Pk.*
Crataegus acclivis *Sarg.*
C. baxteri *Sarg.*
C. beata *Sarg.*
C. beckwithae *Sarg.*
C. benigna *Sarg.*
C. colorata *Sarg.*
C. compta *Sarg.*
C. cupulifera *Sarg.*
C. deweyana *Sarg.*
C. diffusa *Sarg.*
C. dunbari *Sarg.*
C. durobrivensis *Sarg.*
C. ellwangeriana *Sarg.*
C. ferentaria *Sarg.*
C. formosa *Sarg.*
C. fulleriana *Sarg.*
C. gemmosa *Sarg.*
C. glaucophylla *Sarg.*
C. hudsonica *Sarg.*
C. laneyi *Sarg.*
C. leiophylla *Sarg.*
C. lennoniana *Sarg.*
C. macauleyae *Sarg.*
C. maineana *Sarg.*
C. opulens *Sarg.*
C. ornata *Sarg.*
C. parviflora *Sarg.*
C. pedicellata *Sarg.*
C. persimilis *Sarg.*
C. rubicunda *Sarg.*
C. spissiflora *Sarg.*
C. streeterae *Sarg.*
C. tenuiloba *Sarg.*
C. verecunda *Sarg.*
Craterellus taxophilus *Thom*
Dipsacus laciniatus *L.*
Eocronartium typhuloides *Atk.*
Falcata pitcheri (*T. & G.*) *Kuntze*
Fusarium aquaeductuum *R. & R.*
Galera capillaripes *Pk.*
Gyrostachys ochroleuca *Rydb.*
Hypholoma rugocephalum *Atk.*
Hypomyces banningiae *Pk.*
H. inaequalis *Pk.*
Lachnocladium semivestitum *B. & C.*
Lactarius brevis *Pk.*
L. colorascens *Pk.*
Pholiota appendiculata *Pk.*
Salix serissima (*Bail.*) *Fern.*
Sisyrinchium arenicola *Bickn.*
Stachys sieboldi *Miq.*
Teucrium boreale *Bickn.*
Viola amoena *Le Conte*
V. latiuscula *Greene*
V. septentrionalis *Greene*
Zygodesmus granulosus *Pk.*

Not new to the herbarium

Agaricus abruptibulbus *Pk.*
A. campester *L.*
A. subrufescens *Pk.*
Amanita caesarea *Scop.*
A. muscaria *L.*
Amanitopsis vaginata (*Bull.*) *Roze*
A. volvata (*Pk.*) *Sacc.*
Antennaria ambigens (*Greene*) *Fern.*
A. canadensis *Greene*
A. fallax *Greene*
A. neglecta *Greene*
A. petaloidea *Fern.*
A. plantaginea *R. Br.*
Actaea rubra (*Ait.*) *Willd.*

Anthemis cotula *L.*
Allium tricoccum *Ait.*
Alsine borealis (*Bigel.*) *Britton*
Aquilegia vulgaris *L.*
Arenaria serpyllifolia *L.*
Arisaema triphyllum (*L.*) *Torr.*
Aristolochia clematitis *L.*
Artemisia stelleriana *Bess.*
Asplenium angustifolium *Mx.*
Asterodon ferruginosum *Pat.*
Bactridium ellisii *Berk.*
Bartonia virginica (*L.*) *B. S. P.*
Bidens frondosa *L.*
Blephilia hirsuta (*Pursh*) *Torr.*
Blephariglottis ciliaris (*L.*) *Rydb.*
B. grandiflora (*Bigel.*) *Rydb.*
Blitum capitatum *L.*
Botrychium dissectum *Spreng.*
B. simplex *Hitch.*
B. obliquum *Muhl.*
B. elongatum *G. & H.*
B. habereri *Gilb.*
B. oneidense *Clute*
Boletus clintonianus *Pk.*
B. cyanescens *Bull.*
B. eximius *Pk.*
B. felleus *Bull.*
B. frostii *Russell*
B. illudens *Pk.*
B. nebulosus *Pk.*
B. rubropunctus *Pk.*
Boletinus grisellus *Pk.*
B. porosus (*Berk.*) *Pk.*
Bovista plumbea *Pers.*
Brasenia purpurea (*Mx.*) *Casp.*
Brassica arvensis (*L.*) *B. S. P.*
B. rapa *L.*
Callitriche heterophylla *Pursh*
Cantharellus floccosus *Schw.*
C. cinnabarinus *Schw.*
Carex castanea *Wahl.*
C. comosa *Boott*
C. crawei *Dew.*
C. formosa *Dew.*
C. hitchcockiana *Dew.*
C. lur. exudans *Bail.*
C. setifolia (*Dew.*) *Britton*
Chamaedaphne calyculata (*L.*) *Moench*
Clavaria cristata *Pers.*
C. botrytes *Pers.*
C. platyclada *Pk.*
Claytonia caroliniana *Mx.*
Clitocybe albissima *Pk.*
C. candicans *Pers.*
C. centralis *Pk.*
C. clavipes *Pers.*
C. cyathiformis *Fr.*
C. eccentrica *Pk.*
C. ochropurpurea *Berk.*
Cercospora circumscissa *Sacc.*
Collybia nigrodisca *Pk.*
Coprinus micaceus *Fr.*
Convolvulus spithameus *L.*
Cornus canadensis *L.*
Cortinarius cinnamomeus *Fr.*
Cudonia circinans (*Pers.*) *Fr.*
C. lutea (*Pk.*) *Sacc.*
Cudoniella marcida (*Mull.*) *Sacc.*
Crataegus holmesiana *Ashe*
C. macracantha *Lodd.*
C. pringlei *Sarg.*
C. submollis *Sarg.*
C. succulenta *Lk.*
C. tomentosa *L.*
Daphne mezereum *L.*
Daedalea unicolor (*Bull.*) *Fr.*
Dianthera americana *L.*
Diplodia conigena *Desm.*
Discina orbicularis *Pk.*
Eatonia pennsylvanica (*DC.*) *Gr.*
Eleocharis acicularis (*L.*) *R. & S.*
E. acuminata (*Mx.*) *Nees.*
E. pal. vigens *Bail.*
E. pal. glaucescens (*Willd.*)
Eragrostis eragrostis (*L.*) *Karst.*
Eriophorum alpinum *L.*
Erythronium americanum *Ker.*
Eurotium herbariorum (*Wigg*) *Lk.*
Fagopyrum tataricum (*L.*) *Gaertn.*
Filix bulbifera (*L.*) *Underw.*
Fragaria americana (*Porter*) *Britton*
F. vesca *L.*
Fistulina hepatica *Fr.*
Fraxinus nigra *Marsh.*
Geoglossum ophioglossoides (*L.*) *Sacc.*
G. velutipes *Pk.*

Geum canadense *Jacq.*
Gratiola aurea *Muhl.*
Gyalecta pineti (*Schrad.*) *Tuckm.*
Gyrostachys cernua (*L.*) *Kuntze*
G. stricta *Rydb.*
G. plantaginea (*Raf.*) *Britton*
Helvella infula *Schaeff.*
Hieracium praealtum *Vill.*
Hudsonia tomentosa *Nutt.*
Hydnum adustum *Schw.*
H. imbricatum *L.*
H. fennicum *Karst.*
H. zonatum *Batsch*
H. vellereum *Pk.*
Hydrangea arborescens *L.*
Hygrophorus flavodiscus *Frost*
H. fuliginosus *Frost*
H. immutabilis (*Pers.*) *Fr.*
H. laurae decipiens *Pk.*
H. pratensis (*Pers.*) *Fr.*
Hypholoma incertum *Pk.*
H. sublateritium *Schaeff.*
Ilex verticillata (*L.*) *Gray*
Iris versicolor *L.*
Juncus acuminatus *Mx.*
J. brachycephalus (*Engelm.*) *Buch.*
J. balticus *Willd.*
J. marginatus *Rostk.*
Juniperus nanus *Willd.*
Lactarius alpinus *Pk.*
Larix laricinus (*Du Roy*) *Koch*
Lathyrus myrtifolius *Muhl.*
L. volemus *Fr.*
Lentinus lepideus *Fr.*
L. suavissimus *Fr.*
Lenzites sepiaria *Fr.*
Lepiota cepaestipes *Sow.*
Leptoglossum luteum (*Pk.*) *Sacc.*
Leptorchis loesellii (*L.*) *MacB.*
Lithospermum officinale *L.*
Lobelia cardinalis *L.*
Lilium superbum *L.*
Lychnis chalcedonica *L.*
L. alba *Mill.*
Limnorchis dil. linearifolia *Rydb.*
Lycium vulgare (*Ait.*) *Dunal*
Malus coronaria (*L.*) *Mill.*
Marasmius res. candidissima *Pk.*
M. oreades *Fr.*
Mentha canadensis *L.*
Mikania scandens *Willd.*
Myriophyllum verticillatum *L.*
Morchella bispora *Sor.*
M. deliciosa *Fr.*
Naumbergia thyrsiflora (*L.*) *Duby*
Naias flexilis (*Willd.*) *R. & S.*
Omphalia oculus *Pk.*
Onagra oakesiana (*Gr.*) *Britton*
Osmunda claytoniana *L.*
Oxalis cymosa *Small*
O. corniculata *L.*
Panax quinquefolium *L.*
Panicum lanuginosum *Ell.*
Peramium pubescens *Willd.*
Phacelia dubia (*L.*) *Small*
Phlox subulata *L.*
Pholiota adiposa *Fr.*
P. togularis (*Bull.*) *Fr.*
Phytophthora infestans (*Mont.*) *De By.*
Picea canadensis (*Mill.*) *B. S. P.*
P. mariana (*Mill.*) *B. S. P.*
Pleurotus ostreatus (*Jacq.*) *Fr.*
P. ulmarius *Fr.*
Pluteus cervinus (*Schaeff.*) *Fr.*
Polygonum lapathifolium *L.*
Polystictus pergamenus *Fr.*
P. pseudopergamenus *Thum.*
Potamogeton natans *L.*
Potentilla argentea *L.*
Protomyces erythronii *Pk.*
Prunus americana *Marsh.*
P. cuneata *Raf.*
P. nigra *Ait.*
P. pennsylvanica *L.*
Pterospora andromedea *Nutt.*
Quercus acuminata (*Mx.*) *Houda*
Q. prinos *L.*
Q. nana (*Marsh.*) *Sarg.*
Ranunculus hispidus *Mx.*
Rhamnus cathartica *L.*
Rosa sayi *Schw.*
R. setigera *Mx.*
Rubus canadensis *L.*
R. nigrobaccus *Bail.*
R. odoratus *L.*
Rudbeckia hirta *L.*
R. laciniata *L.*
Rumex acetosa *L.*
Russula compacta *Frost*

R. earlei *Pk.*
R. flavida *Frost*
R. lepida *Fr.*
R. magnifica *Pk.*
R. mariae *Pk.*
R. virescens (*Schaeff.*) *Fr.*
Rhynchospora alba (*L.*) *Vahl.*
Salix amygdaloides *Anders.*
S. pet. gracilis *Anders.*
Sarracenia purpurea *L.*
Scirpus pedicellatus *Fern.*
S. occidentalis (*Wats.*) *Chase*
Scrophularia marylandica *L.*
Selaginella apus (*L.*) *Spring.*
Silene vulgaris (*Moench*) *Garcke*
S. antirrhina *L.*
Sisymbrium altissimum *L.*
Sisyrinchium angustifolium *Mill.*
Smilax hispida *Muhl.*
Solidago uniligulata (*DC.*) *Porter*
Specularia perfoliata (*L.*) *DC.*
Stachys aspera *Mx.*
S. palustris *L.*
Stereum complicatum *Fr.*
S. spadiceum *Fr.*
Scleroderma vulgare *Hornem.*
Teucrium boreale *Britton*
Thymus serpyllum *L.*
Tricholoma personatum *Fr.*
Urnula craterium (*Schw.*) *Fr.*
Vagnera stellata (*L.*) *Morong*
Veronica byzantina (*S. & S.*) *B. S. P.*
Viburnum dentatum *L.*
V. lentago *L.*
V. opulus *L.*
Viola blanda *Willd.*
V. pap. domestica (*Bickn.*) *Poll.*
V. palm. dilatata *Ell.*
V. pubescens *Ait.*
V. rotundifolia *Mx.*
V. sororia *Willd.*
V. scabriuscula (*T. & G.*) *Schw.*
Xyris montana *Ries*
Zygadenus elegans *Pursh*
Total 325

Entomology

CONTRIBUTIONS TO COLLECTION OCT. 16, 1903–OCT. 15, 1904

Hymenoptera

Megachile sp., leaf cutter bee, work on rose, Oct. 26, **O. Q. Flint,** Athens N. Y.

Formica pennsylvanica DeG., black ant, work on spruce, Feb. 5, **William B. Young,** Lake Placid N. Y.

Neuroterus batatus Bass., oak potato gall on oak, Sep. 1, through **Country Gentleman,** Westport Mass.

Tremex columba Linn., pigeon tremex, adult on maple, Sep. 15, **J. E. Sanford,** Fredonia N. Y.

Harpiphorus tarsatus Say, larvae on Cornus, July 28, **F. E. Dawley,** Syracuse N. Y.

Coleoptera

Scolytus rugulosus Ratz., fruit tree bark beetle, work in plum, Ap. 8, **Helen Blydenburgh,** Smithtown Branch L. I.

Madarus undulatus Say, Nov. 2, **J. R. de la Torre Bueno,** Van Cortlandt Park N. Y.

Otiorhynchus sulcatus Fabr., adult on strawberry, June 24, **Thomas Cunningham,** Vancouver, British Columbia

O. ovatus Linn., adult on strawberry, June 24, **Thomas Cunningham,** Vancouver, British Columbia

Hemantus floralis Linn., adult, Sep. 12, **Richard Lohrmann,** Herkimer N. Y.

Bruchus pisorum Linn., pea weevil, adults, Oct. 28, **Mrs Wendell Dorn,** Pattersonville N. Y.

Phyllotreta vittata Fabr., adult on radish, July 1, **G. S. Graves,** Newport N. Y.

Haltica ignita Ill., adult on elm, June 27, **G. S. Graves,** Newport **N. Y.**

Galerucella luteola Müll., elm leaf beetle, pupae and larvae on elm, July 19, **C. L. Williams,** Glens Falls N. Y.

Graphops pubescens Melsh., Nov. 2, **J. R. de la Torre Bueno,** Van Cortlandt Park **N. Y.**

Saperda populnea Linn., oviposition scars on twigs, July 25, **Dr L. Reh,** Hamburg, Germany

Centrodera decolorata Harr., adult on beech, July 1, **G. S. Graves,** Newport N. Y.

Hylotrupes bajulus Linn., adult, June 28, **Helen R. Burns,** Yonkers N. Y.

Osmoderma scabra Beauv., adult on pear, June 15, **Mrs A. Lansing,** Albany N. Y.

Dorcus parallelus? Say, larva on appletree, Oct. 17, **G. S. Graves,** Newport N. Y.

Sitodrepa panicea Linn., drug store beetle, adult, Aug. 24, **Warren L. Bradt, Albany N. Y.**

Drasterius elegans Fabr., larvae on potatoes, May, **C. B. Bassett,** Beerston N. Y.

Alaus oculatus Linn., owl beetle, adult, June 8, **J. Hannam Clark,** Coldwater N. Y.

Cryptophagus sp., beetles on dried, moldy squashes, Feb. 15, **C. H. Peck,** Menands N. Y.

Silvanus surinamensis Linn., saw-toothed grain beetle, adult in house, July 12, **R. D. Palmateer,** Waterford N. Y.

Necrophorus americanus Oliv., American carrion beetle, adult, Aug. 18, through **Country Gentleman,** Fair Haven N. J.

Smilia misella Lec., adult on San José scale, Nov. 24, **E. S. Miller,** Germantown N. Y.

Lebia grandis Hentz., Nov. 2, **J. R. de la Torre Bueno,** Van Cortlandt Park N. Y.

List of larvae from **Dr F. Meinert,** Copenhagen, Denmark: Dytiscidae—Hyphydrus ovatus Laccophilus hyalinus DeG.? L. minutus Fabr.? Cremidotus caesar Duftrchm., Haliplus ruficollis DeG., Ilybius fenestratus Fabr., Deronectes (Hydroporus) depressus Fabr.

Diptera

Gastrophilus equi Fabr., horse bot fly, egg on hairs of a boa, May 3, **P. L. Huested,** Blauvelt N. Y.

Pegomyia vicina Lintn., beet leaf miner, larva on beet, June 28, **George T. Powell,** Lenox Mass.

Erax bastardii Macq., robber fly, adult, July 28, **J. E. West,** Poughkeepsie N. Y.

Culex melanurus Coq., larvae, **H. G. Dyar,** Washington D. C.

Culex aurifer Coq., larvae and adults, **H. G. Dyar,** Washington, D. C

C. triseriatus Say, larvae, **H. G. Dyar,** Washington D. C.

C. dupreei Coq., larvae, **H. G. Dyar,** Washington D. C.

C. restuans Theo., larvae, Nov. 2, **J. R. de la Torre Bueno,** Staten Island N. Y.

C. sylvestris Theo., larvae, Nov. 2, **J. R. de la Torre Bueno,** Staten Island N. Y.

C. jamaicensis Theo., larvae, Nov. 2, **J. R. de la Torre Bueno,** Staten Island N. Y.

C. dyari Coq., larvae, **H. G. Dyar,** Washington D. C.

C. atropalus Coq., larvae and adult, **H. G. Dyar,** Washington D. C.

C. discolor Coq., larvae, **H. G. Dyar,** Washington D. C.

C. sollicitans Walk., male and larvae, Nov. 2, **J. R. de la Torre Bueno,** Staten Island N. Y.

Theobaldia incidens Thomson, larvae, **H. G. Dyar,** Washington D. C.

Psorophora ciliata Fabr., adults and larvae, Nov. 2, **J. R. de la Torre Bueno,** Staten Island N. Y.

Sciara ocellaris O. S., larvae on maple, June 4, **P. L. Huested,** Blauvelt N. Y.

Lasioptera vitis O. S., larvae on grape, June 8, **David Muirhead,** New Brighton N. Y.

?Cecidomyia persicoides O. S., hickory peach gall on hickory, Sep. 23, **A. Zabriskie,** Barrytown N. Y.

Cecidomyia verrucicola O. S., adult on Tilia, July 23, **G. S. Graves,** Newport N. Y.

C. pellex O. S., larvae on ash, May 30, **O. Q. Flint,** Athens N. Y.

Larvae received from **Dr F. Meinert,** Copenhagen, Denmark: Thalacrocera replicata L., Trichocera maculipennis Meig., Mochlonyx culiciformis DeG., Corethra plumicornis Fabr., Dixa aprilina Meig., Corethra pallida Fabr., Chironomus venustus Fries., Tanypus sp., Ceratopogon bipunctatum Gmel., Ceratopogon circumdatum Staeg., Miastor metraloas Mein.

Siphonaptera

Ceratopsyllus serraticeps Gerv., cat and dog flea, Aug. 16, **G. S. Kidder,** Port Henry N. Y.

Lepidoptera

Anosia plexippus Linn., adult on Asclepias, July 25, **Frances McCarty,** Albany N. Y.

Sphecodina abbotii Swains, larva, July 5, **J. J. Smith,** Albany N. Y.

Plegethontius quinquemaculata Haworth, Sep. 30, **H. O. Bassett,** Schenectady N. Y.

Ceratomia amyntor Hübn, hawk moth caterpillar on elm, Aug. 16, **Mrs Abraham Lansing,** Albany N. Y.

Antherea yama-maia Gner., Japanese silkworms, larvae on scrub oak, May 31, **L. H. Joutel,** New York

Philosamia cynthia Drury, Ailanthus worm, cocoon, June 10, **H. C. Hearman,** Lansingburg N. Y.

Tropaea luna Linn., Luna moth, adult on walnut, June 14, **Rev. A. M. Kling,** Eminence N. Y.

Halisidota caryae Harr., hickory Tussock moth, larvae, Aug. 12, **Raymond Watson,** Lockport N. Y.

Alypia octomaculata Fabr., 8-spotted forester, larva on grape, June 8, **David Muirhead,** New Brighton N. Y.

Agrotis messoria Harr., dark sided cut worm, larvae, June 3, **K. L. Palmatin,** Catskill N. Y. Same, June 28, B. F. Haskell, Portland Me.

Papaipema nitela Guen., stalk borer, larva on tomato, June 28, J. M. Dolph, Port Jervis N. Y. Same on corn, June 29, **D. F. Meskil,** Highlands N. Y.

Schizura concinna Sm. & Abb., red-humped appletree caterpillar, larvae on apple, Sep. 7, **W. H. Gifford,** Onondaga co. N. Y.

Malacosoma americana Fabr., tent caterpillar, eggs on apple, Ap. 8, **Helen Blydenburgh,** Smithtown Branch L. I.

Megalopyge opercularis Sm. & Abb., rabbit moth, cocoon on maple, Aug. 2, **Chester L. Whitaker,** Somerville Mass.

?Zeuzera pyrina Linn., leopard moth, work? on ?Norway maple, Nov. 24, **Ferdinand Fish,** Brooklyn N. Y.

Cossus centerensis Lint., larvae on Populus deltoides Marsh, July 26, **S. C. Bradt,** Albany N. Y.

Thiodia signatana Clem. on maple, Sep. 23, **Mrs Williamson,** Onteora N. Y.

?Gelechia obliquistrigella Chamb., red-spruce bud worm, larvae on red spruce, Oct. 23, **C. R. Pettis,** Saranac Inn N. Y.

Lithocolletis hamadryadella Clem., oak leaf miner, larvae on oak, Aug. 8, **Mrs Isabella M. Banks,** New Hamburg N. Y.

Neuroptera

Corydalis cornuta Linn., hellgramite fly, adult, June 27, **Albert Spencer,** Albany N. Y.

Chaulioides pectinicornis Linn., comb horned fish fly, July 26, **O. Q. Flint,** Athens N. Y.

Hemiptera

Zaitha fluminea Say, waterbug, adult bearing egg mass, July 18, **O. Q. Flint,** Athens N. Y.

Lygus pratensis Linn., Nov. 2, **J. R. de la Torre Bueno,** Van Courtlandt Park N. Y.

Ceresa bubalus Fabr., Buffalo tree hopper on apple, Oct. 3, **Frank H. Knox,** Troy N. Y.

Trioza tripunctata Fitch, bramble flea louse, adult on wild blackberry, Sep. 1, **Cyrus R. Crosby,** Penn Yan N. Y.

Pachypsylla celtidis-mamma Riley, jumping plant louse, gall on hackberry leaf, Celtis, Aug. 2, **O. Q. Flint,** Athens N. Y.

Phylloxera caryaecaulis Fitch, hickory gall aphis, galls on hickory, Ap. 6, **G. T. Powell,** Ridgefield Ct.

Schizoneura americana Riley, elm leaf wooly aphis, June 8, **F. W. Wells,** Saratoga Springs N. Y. Same, nymphs on elm, July 6, A. T. Sutcliffe, Chippewa Bay N. Y.

Pemphigus imbricator Fitch, on beech, Oct. 29, **G. S. Graves,** Newport N. Y.

Aleyrodes vaporariorum West, on fuchsia, Jan. 12, **Mrs W. H. Harrison,** Lebanon Springs N. Y.

Chermes pinicorticis Fitch, plant louse on balsam, Sep. 3, **John T. Sackett,** South Amenia N. Y.

Pulvinaria innumerabilis Rathv., on maple, June 30, through **James H. Stoller** (Schenectady N. Y.) Riverhead N. Y.

Lecanium? cerasifex Fitch, cherry Lecanium, adult on pear, May 31, **C. E. Eldridge,** Leon N. Y.

Coccus hesperidum Linn., house Lecanium, adults on fern, March 18, **Mrs E. H. Mairs,** Irvington N. Y.

Eulecanium nigrofasciatum Perg. on maple, Nov. 25, **P. L. Huested,** Highland Falls N. Y.

E. tulipiferae Cook, tulip scale, young on tulip, Feb. 15, **P. L. Huested,** Milton N. Y. Same, adult on tulip, July 9, **Truman H. Baldwin,** Nyack-on-the-Hudson N. Y.

Chionaspis corni Cooley, adults on Cornus sanguinea, Feb. 6, **B. D. Van Buren,** Geneva N. Y. Same, adult on Cornus, Feb. 23, **Thomas Cunningham,** Vancouver, British Columbia

C. pinifoliae Fitch, pine leaf scale insect on pine, Dec. 9, **G. L. Flanders,** Rochester N. Y. Same, on pine, Oct. 12, **G. G. Atwood,** Albany N. Y.

C. furfura Fitch, scurfy bary louse on crab apple, Ap. 6, **J. O. Carlton,** New York city

Chrysomphalus aonidum Linn., adults on rubber plant, Dec. 7, **C. H. Peck,** Menands N. Y.

Aulacaspis pentagona Targ., West Indian peach scale on flowering cherry, Ap. 28, **T. F. Niles,** Chatham N. Y.

A. rosae Bouche, rose scale, adult on blackberry, Dec. 14, State Department Agriculture, Ohio

Aspidiotus ancylus Putn., Putnam's scale, adults on Cornus florida, Dec. 12, State Department Agriculture, Flushing N. Y.

A. forbesi Johnson, cherry scale on pear?, Ap. 16, **Fred T. Wiley,** Geneva N. Y.

A. perniciosus Comst., San José scale, adults, on crabapple, Ap. 6, **J. O. Carlton,** New York. Same on currant, Ap. 8, **Helen Blydenburgh,** Smithtown Branch L. I. Same on currant, Ap. 20, **S. B. Huested,** Blauvelt N. Y. Same on Japan weeping cherry, imported directly from Japan, Ap. 23, **G. G. Atwood.** Same on apple, peach, currant and Liburnum, May 13, **Miss M. J. Tyers,** Dobbs Ferry N. Y. Same on peach, May 21, **S. F. Skidmore,** East Hampton N. Y. Same, June 28, **H. Steers,** Larchmont N. Y. Same, all stages on crabapple, July 11, **David Muirhead,** West New Brighton N. Y. Same on currant, July 15, **G. T. Powell,** Ghent N. Y. Same, all stages on pear, Aug. 1, **David Muirhead,** West New Brighton N. Y. Same, all stages on pear, Aug. 5, **Mrs Edwin H. Mairs,** Irvington N. Y. Same on plum, Sep. 17, **Myron S. Wheeler,** Berlin Mass.

Lepidosaphes ulmi Linn., oyster shell scale eggs on silver maple, Ap. 9, through *Country Gentleman,* Wallkill N. Y. Same on horse-chestnut, Ap. 22, **T. L. Memikheim,** New Dorp N. Y. Same on

willow, June 2, **J. W. Hand,** East Hampton N. Y. Same on apple, Sep. 15, **E. Spaulding,** Greenville N. Y.

Ohio Coccidae received from **Mr J. G. Sanders,** Ohio State University, Columbus, June 13, 1904: Chionaspis corni Cooley on Cornus amomum, June 30, 1903, at Cedar Point, Erie co. O.; C. pinifoliae (Fitch) on pinus strobus and P. virginiana, Mar. 2, 1903, at Columbus, O.; C. gleditsiae Sanders (Cotypes) on Gleditsia triacanthos, Mar. 11, 1903, at Columbus O.; C. longiloba Cooley on Populus deltoides (Cottonwood) Ap. 14, 1904, at Painesville O.; C. salicis=nigrae (Walsh) on Salix sp. May 10, 1903, at Columbus O.; C. americana Johns. on Ulmus americana, Feb. 16, 1904, at Columbus O.; Chrysomphalus obscurus (Comst.) on Quercus alba, Mar. 15, 1904, at Columbus O.; Aspidiotus juglans-regiae Comst. on Tilia americana, Ap. 4, 1904, at Columbus O.; Aspidiotus piceus Sanders (Cotypes) on Liriodendron tulipifera, July 7, 1903, at Painesville O.; Eulecanium fletcherl (Ckll.) on Juniperus virginiana, Oct. 14, 1903, at Columbus O.

Orthoptera

Oecanthus niveus DeGr., white flower cricket, eggs on plum, Ap. 20, **W. L. Martin,** Middlebrook Va.

Hippiscus tuberculatus Beauv., coral-winged locust, nymph on snow, Mar. 16, **H. A. Van Fredenberg,** Port Jervis N. Y.

Diapheromera femorata Say, walking-stick, adult, Aug. 17, **Miss Grace Smith,** Albany N. Y. Same, adult, Sep. 26, **Miss Rhoda Thompson,** Ballston Spa N. Y.

Tenodera sinensis, mantis, adult on grapevine, Nov. 19, **F. W. Hopper,** Philadelphia Pa.

Ephemeridae

Palingenia bilineata Say, May fiy, adult, July 28, **J. E. West,** Poughkeepsie N. Y.

Trichoptera

Hydropsyche morosa Hag., caddis fly, adult, June 14, **Miss M. B. Sherman,** Ogdensburg N. Y.

Acarina

Phytoptus acericola Garm., gall mite, gall on sugar maple, July 12, **Edwin Buchman,** Valley Falls N. Y.

P. abnormis Garm., gall mite, adult on linden, July 23, **G. S. Graves,** Newport N. Y.

Myriapoda

Scutigera forceps Raf., house centipede, Nov. 21, **J. N. Dolph,** Port Jervis N. Y.

Julus caeruleocinctus Wood, blue-banded milliped, Oct. 17, **G. S. Graves,** Newport N. Y. Same, June 2, **T. A. Cole,** Madison co. N. Y.

Total	161
Grand total accessions	6269+

APPENDIX 2

NEW ENTRIES ON GENERAL RECORD OF LOCALITIES OF AMERICAN PALEOZOIC FOSSILS BELONGING TO THE STATE MUSEUM

Alphabetic list of localities

Amsterdam (Montgomery co.), 3412
Big Creek (Steuben co.), 3370
Black river (Jefferson co.), 3399, 3408
Bonaventure island, P. Q., 3386
Brownville (Jefferson co.), 3408
Cap Blanc, P. Q., 3377, 3380
" Barre, P. Q., 3378
" Bon Ami, P. Q., 3396
Cape Gaspé, P. Q., 3393
Dolbel's brook, P. Q., 3387, 3388
Gaspé basin, P. Q., 3373, 3374, 3383, 3384, 3385
Gaspé bay, P. Q., 3384
Gaspé mountain, P. Q., 3373
Gaveys cove, P. Q., 3395
Grande Grève, P. Q., 3387, 3388, 3389, 3390, 3391, 3392, 3395
Hornellsville (Steuben co.), 3370, 3371, 3372
Honey run (Steuben co.), 3371
Johnson's island, Ohio, 3367
Kelley's island, Ohio, 3368
Lahuquet's cove, P. Q., 3389
Little Gaspé, P. Q., 3390, 3394
Little Gaspé peninsula, P. Q., 3396
Lowville (Lewis co.), 3409, 3410
Marblehead, Ohio, 3366
Mill creek (Lewis co.), 3410
Mt Ste Anne, P. Q., 3382
Mt Joli, P. Q., 3376, 3379, 3381
Penn Yan (Yates co.), 3397
Percé, P. Q., 3375, 3376, 3377, 3379, 3380, 3381, 3382
Percé rock, P. Q., 3375
Pittsford (Monroe co.), 3411
Sandusky, Ohio, 3369
Shiphead, P. Q., 3393
"Spring House" farm (Monroe co.), 3411
Swartwood (Chemung co.), 3398
Valcour island (Lake Champlain), 3413
Watertown (Jefferson co.), 3399, 3400, 3401, 3403, 3404, 3405, 3406, 3407

New York localities according to counties

Names in italics are new to the record

CHEMUNG CO.
Swartwood

JEFFERSON CO.
Black river
Brownville
Watertown

LEWIS CO.
Lowville
Mill creek

MONROE CO.
Pittsford
"Spring House" farm

MONTGOMERY CO.
Amsterdam

STEUBEN CO.
Big Creek
Hornellsville
Honey run

YATES CO.
Penn Yan

Index to formations

Lower Siluric, 3376, 3381
Chazy limestone, 3413
Trenton limestone, 3412
Siluric, 3380, 3382, 3386
Salina (Pittsford shale), 3411
Upper? Siluric, 3379
Lower Devonic, 3375, 3377, 3378, 3384, 3385
Onondaga limestone, 3366, 3367, 3368, 3369
Devonic, 3382
Devonic? (Gaspé sandstone) 3373, 3374, 3383, 3387
Devonic (Grande Grève limestone), 3388, 3389, 3390, 3391, 3392, 3393, 3394, 3395, 3396
Cashaqua shales, 3397
Ithaca beds, 3398
Chemung, 3370, 3371, 3372

Record of localities

3366 Onondaga limestone. Marblehead O. E. V. Morse, Lorain O. Exchange.

3367 Onondaga limestone. Johnson's island, Ohio. E. V. Morse, Lorain O. Exchange.

3368 Onondaga limestone. Kelley's island, Ohio. E. V. Morse, Lorain O. Exchange.

3369 Onondaga limestone. Sandusky O. E. V. Morse, Lorain O. Exchange.

3370 Chemung beds. Big Creek, 2 miles north of Hornellsville, Steuben co. C. A. Hartnagel, collector. 1903.

3371 Chemung beds. Honey run, 2 miles southwest from Hornellsville, Steuben co. C. A. Hartnagel, collector. 1903.

3372 Chemung beds. Quarry at railroad cut of Erie Railroad, 1 mile west of Hornellsville, Steuben co. C. A. Hartnagel, collector. 1903.

3373 Gaspé sandstone. Portage road and Gaspé mountain, 350′ A. T., back of Gaspé basin, P. Q. J. M. Clarke, collector, 1904.

3374 Gaspé sandstone. Gaspé basin, P. Q., foot of hill at wharf. J. M. Clarke, collector. 1904.

3375 Lower Devonic. Percé rock, Percé P. Q. J. M. Clarke, collector. 1904.

3376 Lower Siluric. South flank of Mt Joli, Percé P. Q. J. M. Clarke, collector. 1904.

3377 Lower Devonic? Lower beds of Cap Blanc, exposure in highway, Percé P. Q. J. M. Clarke, collector. 1904.

3378 Lowest Devonic. Cap Barré, Percé P. Q. J. M. Clarke, collector. 1904.

3379 Upper? Siluric. North flank of Mt Joli, Percé P. Q.

3380 Silurian. Southernmost or highest beds at Cap Blanc, Percé P. Q. J. M. Clarke, collector. 1904.

3381 Lower Silurian. Found loose on shore of Mt Joli, Percé P. Q. J. M. Clarke, collector. 1904.

3382 Pebbles containing Siluric and Devonic fossils from Bonaventure conglomerate (Lower Carboniferous). Mt Ste Anne, Percé P. Q. J. M. Clarke, collector. 1904.

3383 Gaspé sandstone. 3 miles northwest of Gaspé basin, P. Q. on Southwest Arm. J. M. Clarke, collector. 1904.

3384 Lower Devonic? Limestones loose on Southwest Arm, Gaspé bay, 3 miles west of Gaspé basin, P. Q. J. M. Clarke, collector. 1904.

3385 Lower Devonic. Upper Grande Grève limestones from blocks in the stream at peninsula opposite Gaspé basin, P. Q. J. M. Clarke, collector. 1904.

3386 Pebbles with Silurian fossils in the Bonaventure (Lower Carboniferous) conglomerate. Bonaventure island, P. Q. J. M. Clarke, collector. 1904.

3387 Gaspé sandstone? Loose in Dolbel's brook, Grande Grève P. Q. J. M. Clarke, collector. 1904.

3388 Grande Grève limestone. Lowest layers, Dolbel's brook, Grande Grève P. Q. J. M. Clarke, collector, 1904.

3389 Grande Grève limestones, Lahuquet's cóve, Grande Grève P. Q. J. M. Clarke, collector. 1904.

3390 Grande Grève limestones; upper layers. Between Grande Grève and Little Gaspé P. Q. below highway. J. M. Clarke, collector. 1904.

3391 Grande Grève limestones; uppermost layers. On the slope about Grande Grève P. Q. J. M. Clarke, collector. 1904.

3392 Grande Grève limestones; upper layers. Grande Grève P. Q. J. M. Clarke, collector. 1904.

3393 Grande Grève limestones. Shiphead, Cape Gaspé P. Q., 75 feet below top. J. M. Clarke, collector. 1904.

3394 Grande Grève limestones; uppermost beds. Little Gaspé P. Q. J. M. Clarke, collector. 1904.

3395 Grande Grève limestones; upper layers. Gaveys cove, Grande Grève P. Q. J. M. Clarke, collector. 1904.

3396 Grande Grève limestones. Loose at top of Cape Bon Ami, north side of Little Gaspé peninsula, P. Q. J. M. Clarke, collector. 1904.

3397 Cashaqua shales. Goniatites. In a ravine 880 feet A. T., 1 mile south of Penn Yan, Yates co. D. D. Luther, collector. 1904.

3398 Ithaca beds. Crustaceans. Swartwood, Chemung co. E. E. Davis, donor.

3399 .... North bank of Black river half way between the two bridges at the opposite end of Watertown, Jefferson co. A1, beds 1-12. Marcus I. Goldman, collector. 1904.

3400 .... A 2. Corner Wall and Front st., Watertown. 100 feet ± back from A 1, beds 1-2. Marcus I. Goldman, collector. 1904.

3401 .... A 3. 120 feet east of A 2, bed 1. Marcus I. Goldman, collector. 1904.

3402 .... A 4. On south bank of Black river opposite A 1, beds 1-18. Marcus I. Goldman, collector. 1904.

3403 .... Q 1. Brennan & O'Brien's quarry, 2 miles ± north of Mill street bridge, Watertown. Beds 1-11. Marcus I. Goldman, collector. 1904.

3404 .... Q 2. ¾ mile north of Q 1. Beds 1-20. Marcus I. Goldman, collector. 1904.

3405 .... Q 2′. Opposite Q 2. Beds 1-3. Marcus I. Goldman, collector. 1904.

3406 .... Q 3. Quarry in Trenton in bluff at west end City park. Not subdivided into numbered beds. Upper and lower half partly distinguished. 2 divisions. Marcus I. Goldman, collector. 1904.

3407 .... R 1. Along road leading up to city park from west end. Stations 1-7. Marcus I. Goldman, collector. 1904.

3408 ....B 1. North bank of Black river at Brownville, Jefferson co. Beds 1-25. Marcus I. Goldman, collector. 1904.

3409 .... L 1. Contact of sediments and crystallines ¾ to 1 mile west of Lowville, Lewis co. Beds 1-18. Marcus I. Goldman, collector. 1904.

3410 .... L 2. Dutcher quarry beside railroad and Mill creek, Lowville. Beds 1-10. Marcus I. Goldman, collector. 1904.

3411 Pittsford shale at base of Salina group. "Spring House" farm, Pittsford, Monroe co. Frederick Braun, collector. 1904.

3412 Trenton limestone, near Amsterdam, Montgomery co. J. N. Griswold, donor. 1904.

3413 Chazy limestone. Cephalopoda from the dove-colored limestone of Valcour island, N. Y. G. H. Hudson, donor. 1904.

APPENDIX 3

Supplement 2

To the list of type specimens of paleozoic fossils in the possession of the State Museum. The general classified list, covering 5159 numbers, was published as Museum bulletin 65. Supplement 1 was published as part of the annual report of the Paleontologist 1903.

PLANTAE

Fucoides dentatus *see* Diplograptus dentatus
Fucoides serra *see* Tetragraptus serra

CNIDARIA

BRYOGRAPTUS Lapworth

Bryograptus lapworthi Ruedemann

5758 $\frac{3090}{1}$ TYPE Bryograptus lapworthi Ruedemann. New York state museum memoir 7. 1904. p.639, fig.47.
Beekmantown graptolite shale
Deep kill, Rensselaer co. N. Y.
R. Ruedemann, coll. 1901

5759 $\frac{3090}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.1.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lapworthi, pl.5, fig.3; Tetragraptus quadribrachiatus, pl.11, fig.1; T. serra, p.656, fig.56; Phyllograptus anna, pl.15, fig.24.

5760 $\frac{3090}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.2.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lapworthi, pl.5, fig.9; Tetragraptus taraxacum, pl.12, fig.23.

5761 $\frac{3090}{4}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.3.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lapworthi, pl.5, fig.1; Tetragraptus quadribrachiatus, pl.11, fig.1; Tetragraptus serra, p.656, fig.56; Phyllograptus anna, pl.15, fig.24.

5762 $\frac{3090}{5}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.4.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus extensus, pl.14, fig.1.

5763 $\frac{3090}{6}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.5.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lapworthi, pl.5, fig.6; Tetragraptus taraxacum, pl.12, fig.26.

5764 $\frac{3090}{7}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.6.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lapworthi, pl.5, fig.5; Tetragraptus taraxacum, pl.12, fig.26.

5765 $\frac{3090}{8}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.7, 11.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5766 $\frac{3090}{9}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.8.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Tetragraptus amii, p.648, fig.3, pl.11, fig.6 and counterpart of type of Tetragraptus amii, pl.11, fig.7.

5767 $\frac{3090}{10}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.9.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lapworthi, pl.5, fig. 2; Tetragraptus taraxacum, pl.12, fig.23.

5768 $\frac{3090}{11}$ TYPE (2 specimens, fossil and counterpart) Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.10.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5769 $\frac{3090}{12}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.12.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab (other side) with type of Tetragraptus amii, pl.11, fig.7.

Bryograptus pusillus Ruedemann

5770 $\frac{3093}{1}$ TYPE Bryograptus pusillus Ruedemann. New York state museum memoir 7. 1904. p.641, pl.4, fig.21, 22.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

CALLOGRAPTUS Hall

Callograptus *cf.* **diffusus** Hall

5771 $\frac{3095}{1}$ HYPOTYPE Dendrograptus? (Callograptus?) diffusus Hall. Geological survey of Canada; Canadian organic remains, decade 2. 1865. p.132.

Callograptus cf. diffusus Ruedemann. New York state museum memoir 7. 1904. p.586; 587, fig.20.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab (other side) with type of Phyllograptus anna, pl.15, fig.23.

5772 $\frac{3095}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.4, fig.7.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Callograptus salteri Hall

5773 $\frac{3097}{1}$ HYPOTYPE Callograptus salteri Hall. Geological survey of Canada; Canadian organic remains, decade 2. 1865. p.135.

Ruedemann. New York state museum memoir 7. 1904. p.585, fig.18, pl.3, fig.15.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5774 $\frac{3097}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.585, fig.19.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5775 $\frac{3097}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.3, fig.13.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5776 $\frac{3097}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.3, fig.14.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

CARYOCARIS Salter

Caryocaris *cf.* **curvilineatus** Gurley

5777 $\frac{3099}{1}$ HYPOTYPE Caryocaris cf. curvilineatus Gurley. Journal of geology. 1896. 4:738.
Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.17.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus nitidus, p.672, fig.66.

CLIMACOGRAPTUS Hall

Climacograptus? antennarius *see* Climacograptus? (Cryptograptus) antennarius

Climacograptus? (Cryptograptus) antennarius Hall

5778 $\frac{3185}{1}$ HYPOTYPE Climacograptus? antennarius Hall. Geological survey of Canada; Canadian organic remains, decade 2. 1865. p.112.
Climacograptus? (Cryptograptus) antennarius. Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.21.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Glossograptus echinatus, pl.16, fig.31; Trigonograptus ensiformis, pl.17, fig.8.

5779 $\frac{3185}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl. 16, fig.22.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Trigonograptus ensiformis, pl.17, fig.12.

5780 $\frac{3185}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl. 16, fig.23.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

On slab with type of Eunema accola $\frac{7515}{2}$; Dictyonema rectilineatum, p.608, fig.29, pl.3, fig.10; Strophograptus trichomanes, pl.4, fig.17–20.

5781 $\frac{3185}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.24.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

On slab with types of Ptilograptus geinitzianus, pl.4, fig.16; Climacograptus? antennarius, pl.16, fig.25.

5782 $\frac{3185}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.25.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

On slab with types of Ptilograptus geinitzianus, pl.4, fig.16; Climacograptus? (Cryptograptus) antennarius, pl.16, fig.24.

5783 $\frac{3185}{6}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.26.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

Climacograptus pungens Ruedemann

5784 $\frac{3188}{1}$ TYPE Climacograptus pungens Ruedemann. New York state museum memoir 7. 1904. p.730, pl.16, fig.14.

Beekmantown graptolite shale

Mt Moreno, Columbia co. N. Y.

R. Ruedemann, coll. 1903

On slab with type of Phyllograptus anna mut. ultimus, p.715, fig.99.

5785 $\frac{3188}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig. 15.

Beekmantown graptolite shale

Mt Moreno, Columbia co. N. Y.

R. Ruedemann, coll. 1903

On slab with type of Diplograptus laxus, pl.16, fig.2.

5786 $\frac{3188}{3}$ TYPE (2 specimens, original and counterpart) Ruedemann. New York state museum memoir 7. 1904. pl.16, fig. 16.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903
On slab with type of Didymograptus cuspidatus, pl.13, fig.16.

5787 $\frac{3188}{4}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.17.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

5788 $\frac{3188}{5}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.18.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5789 $\frac{3188}{6}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl. 16, fig.19.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

5790 $\frac{3188}{7}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.20.
Beekmantown graptolite shale
Deep kill, N. Y.
R. Ruedemann, coll. 1901

Clonograptus (Goniograptus) sp. nov.
see Goniograptus perflexilis

DAWSONIA Nicholson

Dawsonia monodon Gurley

5791 $\frac{3305}{1}$ HYPOTYPE Dawsonia monodon Gurley. Journal of geology. 1896. 4:88.
Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.21, 23.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with types of Dawsonia monodon, pl.17, fig.22, 24.

5792 $\frac{3305}{2}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.22.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Dawsonia monodon, pl.17, fig.21, 23, 24.

5793 $\frac{3305}{3}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl. 17, fig. 24.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Dawsonia monodon, pl.17, fig.21–23.

5794 $\frac{3305}{4}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.25.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5795 $\frac{3305}{5}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl. 17, fig.26.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Dawsonia tridens Gurley

5796 $\frac{3306}{1}$ **HYPOTYPE** Dawsonia tridens Gurley. Journal of geology. 1896. 4:88.

Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.18.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5797 $\frac{3306}{2}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.19.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5798 $\frac{3306}{3}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.20.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

DENDROGRAPTUS Hall

Dendrograptus? (Callograptus?) diffusus *see* Callograptus cf. diffusus

Dendrograptus flexuosus Hall

5799 $\frac{3307}{1}$ HYPOTYPE Dendrograptus flexuosus Hall. Geological survey of Canada; Canadian organic remains, decade 2. 1865. p.127.

Ruedemann. New York state museum memoir 7. 1904. pl.4, fig.5.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Dendrograptus flexuosus, pl.4, fig.6.

5800 $\frac{3307}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.4, fig.6.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Dendrograptus flexuosus, pl.4, fig.5.

5801 $\frac{3307}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.4, fig.8, 9.

Beekmantown graptolite shale Deep kill, N. Y.
R. Rudemann, coll. 1901

On slab with type of Goniograptus thureaui var. postremus, pl.6, fig.9.

Dendrograptus fluitans Ruedemann

5802 $\frac{3308}{1}$ TYPE Dendrograptus fluitans Ruedemann. New York state museum memoir 7. 1904. p.582, pl.4, fig.11, 12.

Beekmantown graptolite shale Deep kill, N.Y.
R. Ruedemann, coll. 1901

Dendrograptus ? succulentus Ruedemann

5803 $\frac{3309}{1}$ TYPE Dendrograptus? succulentus Ruedemann. New York state museum memoir 7. 1904. p.581, fig.16; p.582, fig.17, pl.4, fig.1.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Desmograptus cancellatus, pl.3, fig.7; Dendrograptus ? succulentus, pl.4, fig.4; Loganograptus logani, pl.9, fig.3; pl.9, fig.4.

5804 $\frac{3309}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.4, fig.2.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5805 $\frac{3309}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.4, fig.3.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab (other side) with type of Desmograptus cancellatus, pl.3, fig.6.

5806 $\frac{3309}{4}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.4, fig.4.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with types of Desmograptus cancellatus, pl.3, fig.7; Dendrograptus ? succulentus, pl.4, fig.1; Loganograptus logani, pl.9, fig.3, 4.

DESMOGRAPTUS Hopkinson

Desmograptus cancellatus Hopkinson

5807 $\frac{3310}{1}$ HYPOTYPE Dictyograptus (Desmograptus) cancellatus Hopkinson. Quarterly journal of the geological society of London. 1875. 31:688.
Desmograptus cancellatus Ruedemann. New York state museum memoir 7. 1904. p.610. pl.3, fig.5.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5808 $\frac{3310}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.3, fig.6.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab (other side) with type of Dendrograptus ? succulentus, pl.4, fig.3.

5809 $\frac{3310}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.610, fig.31, pl.3, fig.7.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with types of Dendrograptus ? succulentus, pl.4, fig.1, 4; Loganograptus logani, pl.9, fig.3, 4.

5810 $\frac{3310}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.3, fig.8.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Desmograptus intricatus Ruedemann

5811 $\frac{3311}{1}$ TYPE Desmograptus intricatus Ruedemann. New York state museum memoir 7. 1904. p.611; 609, fig.30.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5812 $\frac{3311}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.612, fig.33, pl.3, fig.1.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5813 $\frac{3311}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.3, fig.2.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5814 $\frac{3311}{4}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.611, fig.32, pl.3, fig.3.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Trigonograptus ensiformis, pl.17, fig.9.

5815 $\frac{3311}{5}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl. 3, fig.4.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

DICHOGRAPTUS Salter

Dichograptus octobrachiatus Hall (sp.)

5816 $\frac{3312}{1}$ HYPOTYPE Graptolithus octobrachiatus Hall. Geological survey of Canada; report for 1857, 1858. p.122.
Dichograptus octobrachiatus Ruedemann. New York state museum memoir 7. 1904. pl.8, fig.1.
Beekmantown graptolite shale Deep kill, N .Y.
R. Ruedemann, coll. 1901

5817 $\frac{3312}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.8, fig.2.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5818 $\frac{3312}{3}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.8, fig.3.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5819 $\frac{3312}{4}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.8, fig.4.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Didymograptus nicholsoni var. planus, pl.13, fig.10, 13, 14.

5820 $\frac{3312}{5}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.8, fig.5.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Phyllograptus anna, pl.15, fig.27.

5821 $\frac{3312}{6}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.8, fig.6.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5822 $\frac{3312}{7}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.8. fig.7.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5823 $\frac{3312}{8}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.9, fig.1.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Didymograptus similis, pl.14, fig.25, 28; Phyllograptus typus, pl.15, fig.37.

5824 $\frac{3312}{9}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.9, fig.2.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus fruticosus, pl.10, fig.2.

Dictyograptus (Desmograptus) cancellatus *see* Desmograptus cancellatus

Dictyograptus flabelliformis var. conferta *see* Dictyonema flabelliforme *var.* confertum

DICTYONEMA Hall

Dictyonema flabelliforme Eichwald (sp.)

5825 $\frac{3313}{1}$ HYPOTYPE Gorgonia flabelliformis Eichwald. Sil. Schicht. Syst. in Esthland. 1840. p.207.

Dictyonema flabelliforme. Ruedemann. New York state museum memoir 7. 1904. p.601, fig.26.

Upper Cambric graptolite shale

Schaghticoke N. Y.

R. Ruedemann, coll. 1902

5826 $\frac{3313}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.602, fig.27.

Upper Cambric graptolite shale

Schaghticoke N. Y.

R. Ruedemann, coll. 1902

5827 $\frac{3313}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl. 1, fig.1.

Upper Cambric graptolite shale

Schaghticoke N. Y.

R. Ruedemann, coll. 1902

5828 $\frac{3313}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.2.

Upper Cambric graptolite shale

Schaghticoke N. Y.

R. Ruedemann, coll. 1902

On slab with types of Dictyonema flabelliforme, pl.1, fig.5, 8.

5829 $\frac{3313}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.3.

Upper Cambric graptolite shale

Schaghticoke N. Y.

R. Ruedemann, coll. 1902

5830 $\frac{3313}{6}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.4.

Upper Cambric graptolite shale

Schaghticoke N. Y.

R. Ruedemann, coll. 1902

5831 $\frac{3313}{7}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.5.

Upper Cambric graptolite shale

Schaghticoke N. Y.

R. Ruedemann, coll. 1902

On slab with types of Dictyonema flabelliforme, pl.1, fig.2, 8.

5832 $\frac{3313}{8}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.6.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5833 $\frac{3313}{9}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.7.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5834 $\frac{3313}{10}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.8.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902
On slab with types of Dictyonema flabelliforme, pl.1, fig.2, 5.

5835 $\frac{3313}{11}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.9.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5836 $\frac{3313}{12}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.10.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5837 $\frac{3313}{13}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl. 1, fig.11.
Upper Cambrlc graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5838 $\frac{3313}{14}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.12.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5839 $\frac{3313}{15}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1. fig.13.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5840 $\frac{3313}{16}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.14.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5841 $\frac{3313}{17}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.15.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5842 $\frac{3313}{18}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig. 16.
Upper Cambric graptolite shale Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5843 $\frac{3313}{19}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.17.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5844 $\frac{3313}{20}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.18.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5845 $\frac{3313}{21}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.19.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5846 $\frac{3313}{22}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.20.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

5847 $\frac{3313}{23}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.21.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

Dictyonema flabelliforme Eichwald (sp.) *var.* **confertum** (Linnarsson ms.) Brögger

5848 $\frac{3313}{1}a$ HYPOTYPE Dictyograptus flabelliformis var. conferta (Linnarsson ms.) Brögger. Die Sil. Etagen 2 and 3. 1882. p.35.

Dictyonema flabelliforme var. confertum Ruedemann. New York state museum memoir 7. 1904. pl.1, fig.22.

Upper Cambric graptolite shale

Schaghticoke N. Y.
R. Ruedemann, coll. 1902

Dictyonema furciferum Ruedemann

5849 $\frac{3314}{1}$ TYPE Dictyonema furciferum Ruedemann. New York state museum memoir 7. 1904. p.606; 607, fig.28, pl.3, fig.11.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with the counterpart of type of Tetragraptus fruticosus, pl.10, fig.8, used in drawing that figure.

Dictyonema rectilineatum Ruedemann

5850 $\frac{3315}{1}$ TYPE Dictyonema rectilineatum Ruedemann. New York state museum memoir 7. 1904. p.607, pl.3, fig.9.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Tetragraptus quadribrachiatus, pl. 11, fig.2; Glossograptus echinatus, pl.16, fig.32; Diplograptus inutilis, pl.16, fig.12.

5851 $\frac{3315}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.608, fig.29, pl.3, fig.10.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Eunoa accola $\frac{7515}{2}$; Strophograptus trichomanes, pl.4, fig.17–18, 20; Climacograptus antennarius, pl.16, fig.23.

DIDYMOGRAPTUS McCoy

Didymograptus sp. Ruedemann

5852 $\frac{3316}{1}$ HYPOTYPE Didymograptus sp. Ruedemann. New York state museum memoir 7. 1904. p.670, fig.65.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Didymograptus (Leptograptus) sp. nov. *see* Didymograptus gracilis

Didymograptus acutidens Lapworth

5853 $\frac{3317}{1}$ HYPOTYPE Didymograptus acutidens Lapworth ms. em. Elles & Wood. Monograph British graptolites, pt 1. Pal. Soc. vol. for 1901. p.25.
Ruedemann. New York state museum memoir 7. 1904. p.683, fig.77; p.684, fig.78, pl.13, fig.15.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Didymograptus bifidus Hall (sp.)

5854 $\frac{3318}{1}$ HYPOTYPE Graptolithus bifidus Hall. Geological survey of Canada; Canadian organic remains, decade 2. 1865. p.73.
Didymograptus bifidus Ruedemann. New York state museum memoir 7. 1904. p.689; 690, fig.86, pl.15, fig.1.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus similis, pl.14, fig.29.

5855 $\frac{3318}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.691, fig.87.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab (other side) with type of Didymograptus similis, p.678, fig.74.

5856 $\frac{3318}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.2.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Goniograptus geometricus, pl.7, fig.16; Tetragraptus pendens, pl.11, fig.19; Didymograptus similis, p.678, fig.73; D. törnquisti, pl.13, fig.6, 7.

5857 $\frac{3318}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.3.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
Didymograptus caduceus *see* Didymograptus (Isograptus) caduceus

Didymograptus (Isograptus) caduceus Salter emend. Ruedemann

5858 $\frac{3319}{1}$ HYPOTYPE Didymograptus caduceus Salter. Quarterly journal of the geological society of London. 1853. 9:187.
Didymograptus (Isograptus) caduceus Ruedemann *emend.* New York state museum memoir 7. 1904. p.695, fig.89, pl.15, fig.6.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with type of Didymograptus caduceus, pl.15, fig.7.

5859 $\frac{3319}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.7.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with type of Didymograptus caduceus, pl.15, fig.6.

Didymograptus caduceus Salter *mut.* **nanus** Ruedemann

5860 $\frac{3319a}{1}$ TYPE Didymograptus caduceus Salter mut. nanus Ruedemann. New York state museum memoir 7. 1904. p.698, fig.90.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5861 $\frac{3319a}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.8.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with types of Loganograptus logani mut. pertenuis, pl.9, fig.5; Didymograptus incertus, pl.15, fig.14; Glossograptus hystrix, pl.16, fig.29.

5862 $\frac{3319a}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.9.
Beekmantown graptolite shale Deep kill, N.Y.
R. Ruedemann, coll. 1901

Didymograptus cuspidatus Ruedemann

5863 $\frac{3319b}{1}$ TYPE (2 specimens, original and counterpart) Didymograptus cuspidatus Ruedemann. New York state museum memoir 7. 1904. p.684; 684, fig.79; p.685, fig.80, pl.13, fig.16.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903
On slab with type of Climacograptus pungens, pl.16, fig.16.

Didymograptus ellesi Ruedemann

5864 $\frac{3319c}{1}$ TYPE Didymograptus ellesi Ruedemann. New York state museum memoir 7. 1904. p.682; 682, fig.75; pl.14, fig.24.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with type of Didymograptus gracilis, pl.14, fig.16.

5865 $\frac{3319c}{2}$ TYPE Ruedemann New York state museum memoir 7. 1904. p.682, fig.76, pl.14, fig.23.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with type of Didymograptus ellesi, pl.14, fig.22.

5866 $\frac{3319c}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.22.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with type of Didymogr. ellesi, pl.14, fig.23.

Didymograptus extensus Hall (sp.)

5867 $\frac{3319d}{1}$ HYPOTYPE Graptolithus extensus Hall. Geological survey of Canada; report for 1858. p. 132.
Didymograptus extensus Ruedemann. New York state museum memoir 7. 1904. p.669, fig.62, 63.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5868 $\frac{3319d}{2}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.13, fig.17.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Temnograptus noveboracensis, pl.5, fig.16.

5869 $\frac{3319d}{3}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.13, fig.18.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5870 $\frac{3319d}{4}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. p.670, fig.64, pl.14, fig.1.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Bryograptus lapworthi, pl.5, fig.4.

5871 $\frac{3319d}{5}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.2.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus fruticosus, pl.10, fig.4; Tetragraptus serra, pl.11, fig.9.

5872 $\frac{3319d}{6}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.3.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus extensus, pl.14, fig.4.

5873 $\frac{3319d}{7}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.4.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus extensus, pl.14, fig.3.

Didymograptus filiformis Tullberg

5874 $\frac{3319e}{1}$ **HYPOTYPE** Didymograptus filiformis Tullberg. Geol. Fören. Stockh. Förh. 1880, 5:42.

Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.8.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Didymograptus filiformis, pl. 14, fig.9, 11.

5875 $\frac{33.19e}{2}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.9.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Didymograptus filiformis, pl. 14, fig.8, 11.

5876 $\frac{33.19e}{3}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.10.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5877 $\frac{33.19e}{4}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.11.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Didymograptus filiformis, pl.14, fig.8, 9.

5878 $\frac{33.19e}{5}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.12.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus nitidus, pl.14, fig.5.

5879 $\frac{33.19e}{6}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.13.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N.Y.
R. Ruedemann, coll. 1903

5880 $\frac{33.19e}{7}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.14.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Didymograptus forcipiformis Ruedemann

5881 $\frac{33.19f}{1}$ **TYPE** (2 specimens, fossil and counterpart) Didymograptus forcipiformis Ruedemann. New York state museum memoir 7. 1904. p.699, pl.15, fig.10.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

On slab with type of Didymograptus similis, pl.14, fig.26.

5882 $\frac{3319f}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.11.
Beekmantown graptolite shale Mt Moreno, N. Y.
R. Ruedemann, coll. 1903

5883 $\frac{3319f}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.699, fig.91, pl.15, fig.12.
Beekmantown graptolite shale Mt Moreno, N. Y.
R. Ruedemann, coll. 1903

5884 $\frac{3319f}{4}$ TYPE Ruedemann New York state museum memoir 7. 1904. pl.15, fig.13.
Beekmantown graptolite shale Mt Moreno, N. Y.
R. Ruedemann, coll. 1903

Didymograptus gracilis Törnquist

5885 $\frac{3319g}{1}$ HYPOTYPE Didymograptus gracilis Törnquist. Undersökningar öfver Siljansområdets Graptoliter I. 1891. p.17.
Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.15, 21.
Beekmantown graptolite shale
Deep kill, Rensselaer co., N. Y.
R. Ruedemann, coll. 1901

On slab with type of Goniograptus geometricus, pl.7, fig.10.

5886 $\frac{3319g}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.16.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus ellesi, pl.14, fig.24.

4881 $\frac{3319g}{3}=(\frac{3321}{1})$ HYPOTYPE Didymograptus (Leptograptus) sp. nov. Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.589, fig.17.
Didymograptus gracilis Ruedemann, New York state museum memoir 7. 1904. p.533. fig.12, pl.14, fig.17.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with Didymograptus gracilis, pl.14, fig.19, 20.

5887 $\frac{3319g}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.18.

Beekmantown graptolite shale

Mt Moreno, Columbia co. N. Y.

R. Ruedemann, coll. 1903

5888 $\frac{3319g}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.19, 20.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

On slab with type of Didymograptus gracilis, pl.14, fig. 17.

Didymograptus incertus Ruedemann

5889 $\frac{3319h}{1}$ TYPE (2 specimens, fossil and counterpart) Didymograptus incertus Ruedemann. New York state museum memoir 7. 1904. p.700, fig.92, pl.15, fig.14.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

On slab with types of Loganograptus logani mut. pertenuis, pl.9, fig.5; Didymograptus caduceus mut. nanus, pl.15, fig.8; Glossograptus hystrix, pl.16, fig.29.

Didymograptus nanus Lapworth

5890 $\frac{3319i}{1}$ HYPOTYPE Didymograptus indentus var. nanus. Lapworth. Quarterly journal of the geological society of London. 1875. 31: 647.

Didymograptus nanus Ruedemann. New York state museum memoir 7. 1904. p.693, fig.88, pl.15, fig.4.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

On slab with type of Didymograptus nanus, pl.15, fig.5.

5891 $\frac{3319i}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.5.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

On slab with type of Didymograptus nanus, pl.15, fig.4.

Didymograptus nicholsoni Lapworth *var.* **planus** Elles & Wood

5892 $\frac{3319}{1}j$ HYPOTYPE Didymograptus nicholsoni Lapworth var. planus Elles & Wood. Monograph British Graptolites, pt 1. Pal. Soc. vol. for 1901. p.29.

Ruedemann. New York state museum memoir 7. 1904. p.686, fig.83.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5893 $\frac{3319}{2}j$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.685, fig.81, pl.13, fig.10.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Dichograptus octobrachiatus, pl.8, fig.4; Didymograptus nicholsoni var. planus, pl.13, fig.13, 14.

5894 $\frac{3319}{3}j$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.13, fig.11.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5895 $\frac{3319}{4}j$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.13, fig.12.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5896 $\frac{3319}{5}j$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.685, fig.82, pl.13, fig.13, 14.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Dichograptus octobrachiatus, pl.8, fig.4; Didymograptus nicholsoni var. planus, pl.13, fig.10.

Didymograptus nitidus Hall (sp.)

5897 $\frac{3319k}{1}$ HYPOTYPE Graptolithus nitidus Hall. Geological Survey of Canada; report for 1857. p.129.

Didymograptus nitidus Ruedemann. New York state museum memoir 7. 1904. p.672, fig.66.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Caryocaris cf. curvilineatus, pl.17, fig.17.

5898 $\frac{3319k}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.673, fig.70.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus patulus, pl.13, fig.9.

5899 $\frac{3319k}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.13, fig.1.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5900 $\frac{3319k}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.13, fig.2.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5901 $\frac{3319k}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl. 13, fig.3.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5902 $\frac{3319k}{6}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.672, fig.67, pl.13, fig.4.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Goniograptus thureaui var. postremus, pl.6, fig.14.

5903 $\frac{3319k}{7}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.5.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus filiformis, pl.14, fig.12.

5904 $\frac{3319k}{8}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.6.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus similis, pl.12, fig.10.

Didymograptus nitidus Hall *var.* **grandis** Ruedemann

5905 $\frac{3319l}{1}$ TYPE Didymograptus nitidus Hall var. grandis Ruedemann. New York state museum memoir 7. 1904. p.674; 672, fig.68; 673, fig.69,[1] pl.13, fig.5.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

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[1] Erroneously referred to Didymograptus nitidus.

Didymograptus patulus Hall (sp.)

5906 $\frac{3319m}{1}$ HYPOTYPE Graptolithus patulus Hall. Geological survey of Canada; report for 1857. 1858. p.131.

Didymograptus patulus Ruedemann. New York state museum memoir 7. 1904. p.677. fig. 73.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5907 $\frac{3319m}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.676, fig.72, pl.13, fig.9.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus nitidus, p.673, fig.70.

5908 $\frac{3319m}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.675, fig.71, pl.14, fig.7.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Didymograptus similis Hall (sp.)

5909 $\frac{3323}{1}$ HYPOTYPE Graptolithus similis Hall. Geological survey of Canada; Canadian organic remains, decade 2. 1865. p.78.

Didymograptus similis Ruedemann, New York state museum memoir 7. 1904. p.678, fig.73.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Goniograptus geometricus, pl.7, fig.16; Tetragraptus pendens, pl.11, fig.19; Didymograptus törnquisti, pl.13, fig.6, 7; Didymograptus bifidus, pl.15, fig.2.

5910 $\frac{3323}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.678, fig.74

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab (other side) with type of Didymograptus bifidus, p.691, fig.87.

5911 $\frac{3323}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.25, 28.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with types of Dichograptus octobrachiatus, pl.9, fig.1; Phyllograptus typus, pl.15, fig.37.

5912 $\frac{3323}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.26.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903
On slab with type of Didymograptus forcipiformis, pl.15, fig.10.

5913 $\frac{3323}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.27.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with type of Tetragraptus fruticosus, pl.9, fig.11.

5914 $\frac{3323}{6}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.29.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll.1901
On slab with type of Didymograptus bifidus, pl.15, fig.1.

Didymograptus spinosus Ruedemann

5915 $\frac{3324}{1}$ TYPE Didymograptus spinosus Ruedemann. New York state museum memoir 7. 1904. p.688; 689, fig.84.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

5916 $\frac{3324}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.689, fig.85, pl.14, fig.30, 31.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

5917 $\frac{3324}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.14, fig.32.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

Didymograptus törnquisti Ruedemann

5918 $\frac{3325}{1}$ TYPE Didymograptus törnquisti Ruedemann. New York state museum memoir 7. 1904. p.688, pl.13, fig.6, 7.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Goniograptus geometricus, pl.7, fig.16; Tetragraptus pendens, pl.11, fig.19; Didymograptus similis, p.678, fig.73; D. bifidus pl.15, fig.2.

DIPLOGRAPTUS McCoy

Diplograptus dentatus Brongniart (sp.)

5919 $\frac{3330}{1}$ HYPOTYPE Fucoides dentatus Brongniart. Hist. Végét. Foss. 1828. 1:70.
Diplograptus dentatus Ruedemann. New York state museum memoir 7. 1904. p.720, fig.100.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

5920 $\frac{3330}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.10.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

5921 $\frac{3330}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.11.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

5922 $\frac{3330}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.12.
Beekmantown graptolite shale
Deep kill. N. Y.
R. Ruedemann, coll. 1901

On slab with type of Climacograptus? antennarius, pl.16, fig.22.

5923 $\frac{3330}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.13.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

Diplograptus inutilis Hall

5924 $\frac{3335}{1}$ HYPOTYPE D i p l o g r a p t u s   i n u t i l i s   Hall. Geological Survey of Canada; Canadian organic remains, decade 2. 1865. p.111.

Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.12.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of D i c t y o n e m a   r e c t i l i n e a t u m , pl.3, fig.9; T e t r a g r a p t u s   q u a d r i b r a c h i a t u s , pl.11, fig.2; G l o s s o g r a p t u s   e c h i n a t u s , pl.16, fig.32.

5925 $\frac{3332}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.13.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab (other side) with type of D i p l o g r a p t u s   l a x u s , pl.16, fig.4.

Diplograptus laxus Ruedemann

5926 $\frac{3342}{1}$ TYPE D i p l o g r a p t u s   l a x u s Ruedemann. New York state museum memoir 7. 1904. p.722, pl.16, fig.1, 5.

Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

5927 $\frac{3342}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.2.

Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

On slab with type of C l i m a c o g r a p t u s   p u n g e n s , pl.16, fig.15.

5928 $\frac{3342}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.3.

Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

5929 $\frac{3342}{4}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.4.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab (other side) with type of Diplograptus inutilis, pl.16, fig.13.

5930 $\frac{3342}{5}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.7.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Diplograptus laxus, pl.16, fig.8; Phyllograptus anna mut. ultimus, pl.15, fig.29, 30.

5931 $\frac{3342}{6}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.8.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Diplograptus laxus, pl.16, fig.7; Phyllograptus anna mut. ultimus, pl.15, fig.29, 30.

5932 $\frac{3342}{7}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.9, 10.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Diplograptus longicaudatus Ruedemann

5933 $\frac{3344}{1}$ TYPE Diplograptus longicaudatus Ruedemann. New York state museum memoir 7. 1904. p.723, pl.16, fig.11.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901.

GLOSSOGRAPTUS Emmons, Lapworth emend.

Glossograptus echinatus Ruedemann

5934 $\frac{3425}{1}$ TYPE Glossograptus echinatus Ruedemann. New York state museum memoir 7. 1904. p. 725, pl.16, fig.30.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5935 $\frac{3425}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.31.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Climacograptus? (Cryptograptus) antennarius, pl.16, fig.21; Trigonograptus ensiformis, pl.17, fig.8.

5936 $\frac{3425}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.726, fig.102; pl.16, fig.32.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Dictyonema rectilineatum, pl.3, fig.9; Tetragraptus quadribrachiatus, pl.11, fig.2; Diplograptus inutilis, pl.16, fig.12.

Glossograptus hystrix Ruedemann

5937 $\frac{3426}{1}$ TYPE Glossograptus hystrix Ruedemann. New York state museum memoir 7. 1904. p.724, pl.16, fig.27.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Phyllograptus angustifolius, pl.15, fig.31

5938 $\frac{3426}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.725, fig.101, pl.16, fig.28.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5939 $\frac{3426}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.29.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Loganograptus logani mut. pertenuis, pl.9, fig.5; Didymograptus caduceus mut. nanus pl.15, fig.8; D. incertus, pl.15, fig.14.

GONIOGRAPTUS McCoy

Goniograptus geometricus Ruedemann

5940 $\frac{3428}{1}$ TYPE Goniograptus geometricus Ruedemann. New York state museum memoir 7. 1904. p.627; 628, fig.43a.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5941 $\frac{3428}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.628, fig.43b.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5942 $\frac{3428}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p. 628, fig.43c.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5943 $\frac{3428}{4}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.628, fig.43d.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5944 $\frac{3428}{5}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.628, fig.43e.[1]
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab (other side) with type of Tetragraptus quadribrachiatus, pl.11, fig.4.

5945 $\frac{3428}{6}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.628, fig.43f.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5946 $\frac{3428}{7}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.629, fig.45.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Goniograptus geometricus, pl.7, fig.5.

5947 $\frac{3428}{8}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.5, 13.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Goniograptus geometricus, p.629, fig.45.

5948 $\frac{3428}{9}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.10.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus gracilis, pl.14, fig.15.

5949 $\frac{3428}{10}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig. 11.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

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[1] This specimen is more properly to be referred to Goniograptus perflexilis.

5950 $\frac{3428}{11}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p. 629, fig.44. pl.7, fig.12.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Goniograptus geometricus, pl.7, fig.17.

5951 $\frac{3428}{12}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.14.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5952 $\frac{3428}{13}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.15.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Goniograptus thureaui var. postremus, pl.6, fig.10.

5953 $\frac{3428}{14}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.16.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Tetragraptus pendens, pl.11, fig.19; Didymograptus similis, p.678, fig.73; D. törnquisti, pl.13, fig.6,7; D. bifidus, pl.15, fig.2.

5954 $\frac{3428}{15}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.17.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Goniograptus geometricus, p.629, fig.44, pl.7, fig.12.

5955 $\frac{3428}{16}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.18.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus pendens, pl.11, fig.17.

5956 $\frac{3428}{17}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.19.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Goniograptus perflexilis Ruedemann

5957 $\frac{3429}{1}$ TYPE Goniograptus perflexilis Ruedemann. New York state museum memoir 7. 1904. p.625; 625, fig.39a.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5958 $\frac{3429}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.625, fig.39b.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5959 $\frac{3429}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.625, fig.39c, d.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Phyllograptus anna, pl.15, fig.25 and Tetragraptus similis, p.659, fig.58a.

5960 $\frac{3429}{4}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.16, 18.
Beekmantown graptolite shale
Mt Moreno near Hudson, N. Y.
R. Ruedemann, coll. 1903

5961 $\frac{3429}{5}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.626, fig.41, pl.6, fig.17.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5962 $\frac{3429}{6}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.1.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5963 $\frac{3429}{7}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.2.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5964 $\frac{3429}{8}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.3, 4.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Tetragraptus fruticosus, pl.10, fig.1, 3.

5965 $\frac{3429}{9}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.7, fig.6.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5966 $\frac{3429}{10}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.627, fig.42, pl.7, fig.7.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

4879 $\frac{3205}{1}$ TYPE Clonograptus (Goniograptus) sp. nov. Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.582, fig.12.
Goniograptus perflexilis Ruedemann. New York state museum memoir 7. 1904. p.626, fig.40, pl.7, fig.9.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Goniograptus thureaui McCoy *var.* **postremus** Ruedemann.

4923 $\frac{3430}{1}$ TYPE Goniograptus thureaui McCoy var. postremus Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.580; 577, fig.1.
Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.1.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

4924 $\frac{3430}{2}$ TYPE Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.577, fig.2.
Ruedemann. New York state museum memoir 7. 1904. pl.6, fig. 3.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

4925 $\frac{3430}{3}$ TYPE Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.577, fig.3.
Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.2.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

4926 $\frac{3430}{4}$ TYPE Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.578, fig.4.

Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.4.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann coll. 1901

4927 $\frac{3430}{5}$ TYPE Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.578, fig.5.

Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.6.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

4928 $\frac{3430}{6}$ TYPE Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.578, fig.6.

Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.5.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

4929 $\frac{3430}{7}$ TYPE Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.578, fig.7.

Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.7.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

4930 $\frac{3430}{8}$ TYPE Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.578, fig.8.

Ruedemann. New York state museum memoir 7. 1904. pl. 6, fig.8.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

4931 $\frac{3430}{9}$ TYPE Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.579, fig.9.

Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.9.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Dendrograptus flexuosus, pl.4, fig.8,9.

4932 $\frac{3430}{10}$ TYPE Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p. 579, fig.10.

Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.10.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Goniograptus geometricus, pl.7, fig.15.

4933 $\frac{3430}{11}$ TYPE Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.580, fig.11.

Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.11.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5967 $\frac{3430}{12}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.622, fig.37.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5968 $\frac{3430}{13}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.12.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5969 $\frac{3430}{14}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.13.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5970 $\frac{3430}{15}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.14.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus nitidus, pl.13, fig.4

5971 $\frac{3430}{16}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.6, fig.15.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Temnograptus noveboracensis, pl.5, fig.15; Tetragraptus fruticosus, pl.10, fig.5.

Gorgonia flabelliformis *see* Dictyonema flabelliforme

Graptolithus bifidus *see* Didymograptus bifidus

Graptolithus extensus *see* Didymograptus extensus

Graptolithus logani *see* Loganograptus logani

Graptolithus nitidus *see* Didymograptus nitidus

Graptolithus patulus *see* Didymograptus patulus

Graptolithus quadribrachiatus *see* Tetragraptus quadribrachiatus

Graptolithus similis *see* Didymograptus similis

Graptolithus tentaculatus *see* Retiograptus tentaculatus

LOGANOGRAPTUS Hall

Loganograptus logani Hall (sp.)

5972 $\frac{3510}{1}$ HYPOTYPE Graptolithus logani Hall. Geological survey of Canada; report for 1857. 1858. p.115.

Loganograptus logani Ruedemann. New York state museum memoir 7. 1904. pl.9, fig.3.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Desmograptus cancellatus, pl.3, fig.7; Dendrograptus? succulentus, pl.4, fig.1, 4; Loganograptus logani, pl.9, fig.4.

5973 $\frac{3510}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.632, fig. 46, pl. 9, fig. 4.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Desmograptus cancellatus, pl.3, fig.7; Dendrograptus? succulentus, pl.4, fig.1, 4; Loganograptus logani, pl.9, fig.3.

5974 $\frac{3510}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl. 9, fig.6.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with type of Eunoa accola $\frac{7515}{1}$.

Loganograptus logani Hall *mut.* **pertenuis** Ruedemann

5975 $\frac{3511}{1}$ TYPE Loganograptus logani mut. pertenuis Ruedemann. New York state museum memoir 7. 1904. p.633, pl.9, fig.5.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with type of Didymograptus caduceus var. nanus, pl.15, fig.8; Didymograptus incertus, pl.15, fig.14; Glossograptus hystrix, pl.16, fig.29.

PHYLLOGRAPTUS Hall

Phyllograptus angustifolius Hall

5976 $\frac{3605}{1}$ HYPOTYPE Phyllograptus angustifolius Hall. Geological survey of Canada; report for 1857. 1858, p.139.
Ruedemann. New York state museum memoir 7. 1904. p.713, fig.97.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5977 $\frac{3605}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.31.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901.
On slab (other side) with type of Glossograptus hystrix, pl.16, fig.27.

5978 $\frac{3605}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.32.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with counterpart of type of Tetragraptus similis, pl.12, fig.7.

5979 $\frac{3605}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl. 15, fig.33.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5980 $\frac{3605}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.34.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Phyllograptus anna Hall

5981 $\frac{3606}{1}$ HYPOTYPE Phyllograptus anna Hall. Geological survey of Canada; Canadian organic remains, decade 2. 1865. p.124.
Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.23.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab (other side) with type of Callograptus cf. diffusus Hall, p.587, fig.20.

5982 $\frac{3606}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.24.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lap, worthi, pl.5, fig.1, 3; Tetragraptus serra- p.656, fig.56; T. quadribrachiatus, pl.11, fig.1.

5983 $\frac{3606}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.715, fig.98, pl.15, fig.25.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Goniograptus perflexilis, p.625, fig.39c,d; Tetragraptus similis, p.659, fig.58a.

5984 $\frac{3606}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.26.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5985 $\frac{3606}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.27.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Dichograptus octobrachiatus, pl.8, fig.5.

Phyllograptus anna Hall *mut.* **ultimus** Ruedemann

5986 $\frac{3607}{1}$ TYPE Phyllograptus anna mut. ultimus Ruedemann. New York state museum memoir 7. 1904. p.714; 715, fig.99; pl.15, fig.28.

Beekmantown graptolite shale

Mt Moreno, Columbia co. N. Y.

R. Ruedemann, coll. 1903

On slab with type of Climacograptus pungens, pl.16, fig.14.

5987 $\frac{3607}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.29.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

On slab with types of Diplograptus laxus, pl.16, fig.7, 8; Phyllograptus anna mut. ultimus, pl.15, fig.30.

5988 $\frac{3607}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.30.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

On slab with types of Diplograptus laxus, pl.16, fig.7, 8; Phyllograptus anna mut. ultimus, pl.15, fig.29

Phyllograptus ilicifolius Hall

5989 $\frac{3610}{2}$ HYPOTYPE Phyllograptus ilicifolius Hall. Geological survey of Canada; Canadian organic remains, decade 2. 1865. p.121.

Ruedemann. New York state museum memoir 7. 1904. p.707, fig.95.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

On slab with type of Tetragraptus similis, p.659, fig.58b.

5990 $\frac{3610}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.707, fig.96; pl.15, fig.15.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

5991 $\frac{3610}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.16.

Beekmantown graptolite shale Deep kill, N. Y.

R. Ruedemann, coll. 1901

5992 $\frac{3610}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.17.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5993 $\frac{3610}{6}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.18, 21.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus pendens, p.654, fig.55.

5994 $\frac{3610}{7}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.19.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5995 $\frac{3610}{8}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.20.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5996 $\frac{3610}{9}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.22.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus pygmaeus, pl.12, fig.12.

Phyllograptus typus Hall

5997 $\frac{3612}{1}$ HYPOTYPE Phyllograptus typus Hall. Geological survey of Canada; report for 1858. p.137.
Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.35.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5998 $\frac{3612}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.36.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

5999 $\frac{3612}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.15, fig.37.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Didymograptus similis, pl.14, fig.25, 28; Dichograptus octobrachiatus, pl.9, fig.1.

PTILOGRAPTUS Hall

Ptilograptus geinitzianus Hall

6000 $\frac{3660}{1}$ HYPOTYPE Ptilograptus geinitzianus Hall. Geological survey of Canada; Canadian organic remains, decade 2. 1865. p.140.

Ruedemann. New York state museum memoir 7. 1904. pl.4, fig. 16.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Climacograptus ? antennarius, pl.16, fig.24, 25.

Ptilograptus plumosus Hall

6001 $\frac{3652}{1}$ HYPOTYPE (2 specimens, fossil and counterpart) Ptilograptus plumosus Hall. Geological survey of Canada; Canadian organic remains, decade 2. 1865. p.140.

Ruedemann. New York state museum memoir 7. 1904. pl.4, fig.14, 15.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Ptilograptus tenuissimus Ruedemann

6002 $\frac{3654}{1}$ TYPE Ptilograptus tenuissimus Ruedemann. New York state museum memoir 7. 1904. p.591, pl.4, fig.13.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus (Etagraptus) lentus, pl.9, fig.7, 8, 10.

RETIOGRAPTUS Hall

Retiograptus tentaculatus Hall

6003 $\frac{3676}{1}$ HYPOTYPE Graptolithus tentaculatus Hall. Geological survey of Canada; report for 1857. p.134.

Retiograptus tentaculatus Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.33.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6004 $\frac{3675}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.34.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6005 $\frac{3675}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.16, fig.35.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

SIGMAGRAPTUS Ruedemann

Sigmagraptus praecursor Ruedemann

6006 $\frac{3710}{1}$ TYPE Sigmagraptus praecursor Ruedemann. New York state museum memoir 7. 1904. p.702; fig. 93; pl.5, fig.13.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6007 $\frac{3710}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.14.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

STAUROGRAPTUS Emmons

Staurograptus dichotomus Emmons

6008 $\frac{3730}{1}$ HYPOTYPE Staurograptus dichotomus Emmons. American geology. 1855. v.1, pt 2, p.109.
Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.1.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6009 $\frac{3730}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.2.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6010 $\frac{3730}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl. 2, fig.3.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6011 $\frac{3730}{4}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.4.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6012 $\frac{3730}{5}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.5.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6013 $\frac{3730}{6}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.6.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6014 $\frac{3730}{7}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.7.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6015 $\frac{3730}{8}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.8.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6016 $\frac{3730}{9}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.9.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6017 $\frac{3730}{10}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.10.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6018 $\frac{3730}{11}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.11.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6019 $\frac{3730}{12}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.12.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6020 $\frac{3730}{14}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.13.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6021 $\frac{3730}{14}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.14.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6022 $\frac{3730}{15}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.15.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6023 $\frac{3730}{16}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.16.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6024 $\frac{3730}{17}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.17.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6025 $\frac{3730}{18}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.18.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6026 $\frac{3730}{19}$ **HYPOTYPE** (2 specimens, original and counterpart) Ruedemann. New York state museum memoir 7. 1904. pl.2, fig. 19.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6027 $\frac{3730}{20}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.20.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

Staurograptus dichotomus Emmons *var.* **apertus** Ruedemann

6028 $\frac{3731}{1}$ TYPE Staurograptus dichotomus Emmons *var.* apertus Ruedemann. New York state museum memoir 7. 1904. p.617, pl.2, fig.21.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6029 $\frac{3731}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.22.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6030 $\frac{3731}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.23.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

6031 $\frac{3731}{4}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.2, fig.24.
Upper Cambric graptolite shale
Schaghticoke N. Y.
R. Ruedemann, coll. 1902

STROPHOGRAPTUS Ruedemann

Strophograptus trichomanes Ruedemann

6032 $\frac{3790}{1}$ TYPE Strophograptus trichomanes Ruedemann. New York state museum memoir 7. 1904. p.717, pl.4, fig.17.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Eunoa accola $\frac{7515}{2}$; Dictyonema rectilineatum, p.608, fig.29; pl.3, fig.10; Strophograptus trichomanes, pl.4, fig.18, 20; Climacograptus ? antennarius, pl.16, fig.23.

6033 $\frac{3790}{2}$ TYPE Ruedemann. New York State museum memoir 7. 1904. pl.4, fig.18, 20.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Eunoa accola $\frac{7515}{2}$; Dictyonema rectilineatum, p.608, fig.29, pl.3, fig. 10; Strophograptus trichomanes, pl.4, fig.17; Climacograptus ? antennarius, pl.16, fig.23.

TEMNOGRAPTUS Nicholson

Temnograptus noveboracensis Ruedemann

6034 $\frac{3810}{1}$ TYPE Temnograptus noveboracensis Ruedemann. New York state museum memoir 7. 1904. p.619; 619, fig.35.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6035 $\frac{3810}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. p.620, fig.36.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6036 $\frac{3810}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.15.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Goniograptus thureaui var. postremus, pl.6, fig.15; Tetragraptus fruticosus, pl.10, fig.5.

6037 $\frac{3810}{4}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.16.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus extensus, pl.13, fig.17.

6038 $\frac{3810}{5}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.17.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6039 $\frac{3810}{6}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.18.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6040 $\frac{3810}{7}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.19.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6041 $\frac{3810}{8}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.5, fig.20.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

TETRAGRAPTUS Salter

Tetragraptus amii Lapworth, Elles & Wood

6042 $\frac{3825}{1}$ HYPOTYPE (2 specimens, original and counterpart) Tetragraptus amii Lapworth, Elles & Wood. Monograph British Graptolites, pt 1, p.60. Pal. Soc. for 1902.
Ruedemann. New York state museum memoir 7. 1904. p.657, fig.57[1]; pl.11. fig.5.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6043 $\frac{3825}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.6.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lapworthi, pl.5, fig.8; Tetragraptus amii, p.648, fig.3, and counterpart of T. amii, pl.11, fig.7.

6044 $\frac{3825}{3}$ HYPOTYPE (2 specimens, fossil and counterpart) New York state museum memoir 7. 1904. p.648, fig.53; pl.11, fig.7.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lapworthi, pl.5, fig.8, 12; Tetragraptus amii, pl.11, fig.6.

Tetragraptus clarkei Ruedemann

6045 $\frac{3830}{1}a$ TYPE Tetragraptus clarkei Ruedemann. New York state museum memoir 7. 1904. p.652, pl.11, fig.11.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

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[1] Erroneously referred to Tetragraptus serra.

6046 $\frac{38830a}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.12.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6047 $\frac{38830a}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.13.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6048 $\frac{38830a}{4}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.14, 16.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6049 $\frac{38830a}{1}$ TYPE Ruedemann. New York state museum memoir 7 1904. pl.11, fig.15
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Tetragraptus fruticosus Hall (sp.)

6050 $\frac{38831}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.9, fig.11.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus similis, pl.14, fig.27.

6051 $\frac{38831}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.9, fig.12.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6052 $\frac{38831}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.9, fig.13.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6053 $\frac{38831}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.10, fig.1.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Goniograptus perflexilis, pl.7, fig.3, 4; Tetragraptus fruticosus, pl.10, fig.3.

6054 $\frac{3831}{6}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.10, fig.2.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of *Dichograptus octobrachiatus*, pl.9, fig.2.

6055 $\frac{3831}{7}$ **HYPOTYPE** (2 specimens, fossil and counterpart) Ruedemann. New York state museum memoir 7. 1904. pl.10, fig.3.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of *Goniograptus perflexilis*, pl.7, fig.3, 4; *Tetragraptus fruticosus*, pl.10, fig.1.

6056 $\frac{3831}{8}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.10, fig.4.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of *Tetragraptus serra*, pl.11, fig.9; *Didymograptus extensus*, pl.14, fig.2.

6057 $\frac{3831}{9}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.10, fig.5.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of *Goniograptus thureaui* var. *postremus*, pl.6, fig.15; *Temnograptus noveboracensis*, pl.5, fig.15.

6058 $\frac{3831}{10}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.10, fig.6.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6059 $\frac{3831}{11}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.10, fig.7.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6060 $\frac{3831}{12}$ **HYPOTYPE** Ruedemann. New York state museum memoir 7. 1904. pl.10, fig.8.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6061 $\frac{3831}{13}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.10, fig.9.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus taraxacum, pl.12, fig.24.

6062 $\frac{3831}{14}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.10, fig.10.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

Tetragraptus bigsbyi *see* Tetragraptus pygmaeus

Tetragraptus (Etagraptus) lentus Ruedemann

6063 $\frac{3831a}{1}$ TYPE Tetragraptus (Etagraptus) lentus Ruedemann. New York state museum memoir 7. 1904. p.666, pl.9, fig.7, 8, 10.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Ptilograptus tenuissimus, pl.4, fig. 13; Tetragraptus lentus, pl.9, fig.9.

6064 $\frac{3831a}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.9, fig.9.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Tetragraptus lentus, pl.9, fig.7, 8, 10; Ptilograptus tenuissimus, pl.4, fig.13.

Tetragraptus pendens Elles

6065 $\frac{3831b}{1}$ HYPOTYPE Tetragraptus pendens Elles. Quarterly journal of the Geological society of London. 1898. 54: 491.
Ruedemann. New York state museum memoir 7. 1904. p.654, fig.55.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab (other side) with type of Phyllograptus ilicifolius, pl.15, fig.18.

6066 $\frac{3831b}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.17.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Goniograptus geometricus, pl.7, fig.18.

6067 $\frac{3831b}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.18.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus pendens, pl.11, fig.20.

6068 $\frac{3831b}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.19.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Goniograptus geometricus, pl.7, fig.16; Didymograptus similis, p.678, fig.73; Didymograptus törnquisti, pl.13, fig.6, 7; Didymograptus bifidus, pl.15, fig.2.

6069 $\frac{3831b}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.20.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus pendens, pl.11, fig.18.

Tetragraptus pygmaeus Ruedemann

6070 $\frac{3831c}{1}$ TYPE Tetragraptus pygmaeus Ruedemann. New York state museum memoir 7. 1904. p.664, pl.12, fig.11.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6071 $\frac{3831c}{2}$ TYPE Tetragraptus bigsbyi Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.590, fig.18b.
Tetragraptus pygmaeus Ruedemann. New York state museum memoir 7. 1904. pl.12, fig. 12.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Phyllograptus ilicifolius pl.15, fig.22.

6072 $\frac{3831c}{3}$ TYPE T e t r a g r a p t u s b i g s b y i Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.590, fig.18a.

T e t r a g r a p t u s p y g m a e u s Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.13.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6073 $\frac{3831c}{4}$ TYPE T e t r a g r a p t u s p y g m a e u s Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.14.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of T e t r a g r a p t u s s i m i l i s, pl.12, fig.2.

Tetragraptus quadribrachiatus Hall (sp.)

6074 $\frac{3831d}{1}$ HYPOTYPE G r a p t o l i t h u s q u a d r i b r a c h i a t u s Hall. Geological survey of Canada; report for 1857. 1858. p.125.

T e t r a g r a p t u s q u a d r i b r a c h i a t u s Ruedemann. New York state museum memoir 7. 1904. p.646, fig.51.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of T e t r a g r a p t u s q u a d r i b r a c h i a t u s pl.11, fig.3; p.647, fig.52.

6075 $\frac{3831d}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.1.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of B r y o g r a p t u s l a p w o r t h i, pl.5, fig.1, 3; T e t r a g r a p t u s s e r r a, p.656, fig.56; P h y l l o g r a p t u s a n n a, pl.15, fig.24.

6076 $\frac{3831d}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.2.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of D i c t y o n e m a r e c t i l i n e a t u m, pl.3, fig.9; G l o s s o g r a p t u s e c h i n a t u s, pl.16, fig.32; D i p l o g r a p t u s i n u t i l i s, pl.16, fig.12.

6077 3831d/4 HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.3; p.647, fig.52.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus quadribrachiatus p.646, fig.51.

6078 3831d/5 HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.4.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab (other side) with type of Goniograptus geometricus, p.628, fig.43e.

Tetragraptus serra Brongniart (sp.)

6079 3831e/1 HYPOTYPE Fucoides serra Brongniart. Hist. Végét. Foss. 1828. 1:71.
Tetragraptus serra Ruedemann. New York state museum memoir 7. 1904. p.656, fig.56.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lapworthi, pl.5, fig.1, 3; Tetragraptus quadribrachiatus, pl.11, fig.1; Phyllograptus anna, pl.15, fig.24.

6080 3831e/2 HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.8.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6081 3831e/3 HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.11, fig.9,10.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901.

On slab with type of Tetragraptus fruticosus, pl.10, fig.4; Didymograptus extensus, pl.14, fig.2.

Tetragraptus similis Hall (sp.)

6082 3831f/1 HYPOTYPE Phyllograptus similis Hall. Geological survey of Canada; report for 1857. 1858. p.140.
Tetragraptus similis Ruedemann. New York state museum memoir 7. 1904. p.659, fig.58a.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Phyllograptus anna, pl.15, fig.25; Goniograptus perflexilis, p.625, fig.39c.

6083 $\frac{3831f}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.659, fig. 58b.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Phyllograptus ilicifolius, p.707, fig.95.

6084 $\frac{3831f}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.660, fig.59.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with pl.12, fig.8, 9; Tetragraptus taraxacum, pl.12, fig.18.

6085 $\frac{3831f}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. p.660, fig. 60; p.661, fig.61; pl.12, fig. 6.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6086 $\frac{3831f}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.2.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus pygmaeus, pl.12, fig.14.

6087 $\frac{3831f}{6}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.3.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of pl.12, fig.4.

6088 $\frac{3831f}{7}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.4.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of pl.12, fig.3.

6089 $\frac{3831f}{8}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.5.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6090 $\frac{3831f}{9}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.7.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6091 $\frac{3831f}{10}$ HYPOTYPE New York state museum memoir 7. 1904. pl.12, fig.8.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of p.660, fig.59, pl.12, fig.9, Tetragraptus taraxacum, pl.12, fig.18.

6092 $\frac{3831f}{11}$ HYPOTYPE New York state museum memoir 7. 1904. pl.12, fig.9.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of p.660, fig.59, pl.12, fig.8; Tetragraptus taraxacum, pl.12, fig.18.

6093 $\frac{3831f}{12}$ HYPOTYPE New York state museum memoir 7. 1904. pl.12, fig.10.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Didymograptus nitidus, pl.14, fig.6.

Tetragraptus taraxacum Ruedemann

6094 $\frac{3832}{1}$ TYPE Tetragraptus taraxacum Ruedemann. New York state museum bulletin 52; annual report of the state paleontologist. 1902. p.589, fig.16.
Ruedemann. New York state museum memoir 7. 1904. p.663, pl.12, fig.19, 22.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6095] $\frac{3832}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.17.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6096 $\frac{3832}{3}$ TYPE Ruedemann. New York state museum memoir 7, 1904. pl.12, fig.18.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus similis, p.660, fig.59; pl.12, fig. 8, 9.

6097 $\frac{3832}{4}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.20.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6098 $\frac{3832}{5}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.21.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6199 $\frac{3832}{6}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.23.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lapworthi, pl.5, fig.2, 9.

6100 $\frac{3832}{7}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.24.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Tetragraptus fruticosus, pl.10, fig.9.

6101 $\frac{3832}{8}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.25.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6102 $\frac{3832}{9}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.26.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Bryograptus lapworthi, pl.5, fig.5, 6.

Tetragraptus woodi Ruedemann

6103 $\frac{3835}{1}$ TYPE Tetragraptus woodi Ruedemann. New York state museum memoir 7. 1904. p.662, pl.12, fig.1.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of pl.12, fig.15, 16.

6104 $\frac{3835}{2}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig. 15.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of pl.12, fig.1, 16.

6105 $\frac{3835}{3}$ TYPE Ruedemann. New York state museum memoir 7. 1904. pl.12, fig.16.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with types of pl.12, fig.1, 15.

TRIGONOGRAPTUS Nicholson

Trigonograptus ensiformis Hall (sp.)

6106 $\frac{3838}{1}$ HYPOTYPE Retiolites ensiformis Hall. Geological survey of Canada; Canadian organic remains, decade 2. 1865. p.114.
Trigonograptus ensiformis Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.1.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.
R. Ruedemann, coll. 1903

6107 $\frac{3838}{2}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.2.
Beekmantown graptolite shale
Mt Moreno, Columbia co. N. Y.

6108 $\frac{3838}{3}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.3.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with type of pl.17, fig.7.

6109 $\frac{3838}{4}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.4.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6110 $\frac{3838}{5}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.5.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6111 $\frac{3838}{6}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.6.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

6112 $\frac{3838}{7}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.7.
Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901
On slab with type of pl.17,fig.3.

6113 $\frac{3838}{8}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.8.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with types of Climacograptus ? antennarius, pl.16, fig.21; Glossograptus echinatus, pl.16, fig.31.

6114 $\frac{3838}{9}$ HYPOTYPE Ruedemann. New York state museum memoir 7. 1904. pl.17, fig.9.

Beekmantown graptolite shale Deep kill, N. Y.
R. Ruedemann, coll. 1901

On slab with type of Desmograptus intricatus, pl.3, fig.3.

Phyllograptus similis *see* Tetragraptus similis.

Retiolites ensiformis *see* Trigonograptus ensiformis.

ECHINODERMATA

ACTINOCRINUS Miller

Actinocrinus daphne Hall

6115 $\frac{4070}{1}$ TYPE Actinocrinus daphne Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.52.

Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.11, fig.11.

Waverly beds Richfield, Summit co. O.

Actinocrinus eris *see* Aorocrinus eris

Actinocrinus helice *see* Aorocrinus helice

Actinocrinus helice var. eris *see* Aorocrinus eris

Actinocrinus viminalis see Amphoracrinus viminalis

AMPHORACRINUS Austin

Amphoracrinus viminalis Hall (sp.)

6116 $\frac{4015}{1}$ TYPE Actinocrinus viminalis Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.54.

Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.11, fig.12.

Waverly beds Richfield O.

6117 $\frac{4015}{2}$ TYPE Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.11, fig.13.
Waverly beds Richfield O.
C. A. White, coll. 1861

AOROCRINUS Wachsmuth & Springer

Aorocrinus eris Hall (sp.)

6118 $\frac{4024}{1}$ TYPE Actinocrinus helice var. eris Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.53.
Actinocrinus eris Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, p.164, pl.11, fig.9, 10.
Waverly beds Richfield O.

Aorocrinus helice Hall (sp.)

6119 $\frac{4025}{1}$ TYPE Actinocrinus helice Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.53.
Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.11, fig.5, 6.
Waverly beds Richfield O.

6120 $\frac{4025}{2}$ TYPE Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.11, fig.7, 8.
Waverly beds Richfield O.

Cacabocrinus glyptus? var. intermedius *see* Dolatocrinus glyptus *var.* intermedius

Cacabocrinus liratus var. multilira *see* Dolatocrinus liratus *var.* multiliratus

Cacabocrinus speciosus *see* Dolatocrinus speciosus

DECADOCRINUS Wachsmuth & Springer

Decadocrinus aegina Hall (sp.)

6121 $\frac{4125}{1}$ TYPE Scaphiocrinus (Poteriocrinus) aegina Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.57.
Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.11.
Waverly beds Richfield O.
C. A. White, coll. 1861

6122 $\frac{4125}{2}$ TYPE Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.12.
Waverly beds Richfield O.

Decadocrinus lyriope Hall (sp.)

6123 $\frac{4126}{1}$ TYPE Scaphiocrinus (Poteriocrinus) lyriope Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.58.
Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.10.
Waverly beds Richfield O.

Decadocrinus pleias Hall (sp.)

6124 $\frac{4127}{1}$ TYPE Poteriocrinus pleias Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.57.
Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.8.
Waverly beds Richfield O.

Decadocrinus subtortuosus Hall (sp.)

6125 $\frac{4128}{1}$ TYPE Scaphiocrinus subtortuosus Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.59.
Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt2, pl.12, fig.15, 16.
Waverly beds Richfield O.
C. A. White, coll. 1861

On slab with type of Taxocrinus tardus, pl.12, fig.2.

DOLATOCRINUS Lyon

Dolatocrinus glyptus *var.* **intermedius** Hall (sp.)

6126 $\frac{4141}{1}$ TYPE Cacabocrinus glyptus(?) var. intermedius Hall. 15th annual report of the New York state cabinet of natural history. 1862. p.141.
Hamilton shales York, Livingston co. N. Y.
C. A. White and C. Van Deloo, coll. 1860

Dolatocrinus liratus *var.* **multiliratus** Hall (sp.)

6127 $\frac{4142}{1}$ TYPE Cacabocrinus liratus var. multilira Hall. 15th annual report of the New York state cabinet of natural history. 1862. p.139.
Hamilton shales
Menteth point, Canandaigua lake, N. Y.
C. A. White and C. Van Deloo, coll. 1860

Dolatocrinus speciosus Hall (sp.)

6128 $\frac{4143}{1}$ TYPE Cacabocrinus speciosus Hall. 15th annual report of the New York state cabinet of natural history. 1862. p.137.
Onondaga limestone

Forbesiocrinus communis *see* Taxocrinus communis

Forbesiocrinus kelloggi *see* Taxocrinus kelloggi

Forbesiocrinus lobatus var. tardus *see* Taxocrinus tardus

Forbesiocrinus tardus *see* Taxocrinus tardus

MALOCYSTITES Billings

Malocystites emmonsi Hudson

6129 $\frac{4295}{1}$ TYPE Malocystites emmonsi Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.270; 273, fig.1; pl.1, fig.3, 4.
Middle Chazy limestone
Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

6130 $\frac{4295}{2}$ TYPE Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.274, fig.2; pl.1, fig.5, 6.
Middle Chazy limestone
Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

6131 $\frac{4295}{3}$ TYPE Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.276, fig.3; pl.1, fig.7.
Middle Chazy limestone
Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

PACHYLOCRINUS Wachsmuth & Springer

Pachylocrinus merope Hall (sp.)

6132 $\frac{4370}{1}$ TYPE Zeacrinus merope Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.60.

Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.18.
Waverly beds Richfield, Summit co. O.
C. A. White, coll. 1861

Pachylocrinus paternus Hall (sp.)

6133 $\frac{4371}{1}$ TYPE Zeacrinus paternus Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.59.
Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.17.
Waverly beds Richfield O.

PLATYCRINUS Miller

Platycrinus contritus Hall

6134 $\frac{4461}{1}$ TYPE Platycrinus contritus Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.54.
Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.11, fig.4.
Waverly beds Richfield O.

Platycrinus graphicus Hall

6135 $\frac{4462}{1}$ TYPE Platycrinus graphicus Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.55.
Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.11, fig.2.
Waverly beds Richfield O.

Platycrinus richfieldensis Hall & Whitfield

6136 $\frac{4463}{1}$ TYPE Platycrinus richfieldensis Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, p.167, pl.11, fig.1.
Waverly beds Richfield O.
C. A. White, coll. 1861

Poteriocrinus corycia *see* Scaphiocrinus corycia

Poteriocrinus (Scaphiocrinus) corycia *see* Scaphiocrinus corycia

Poteriocrinus crineus *see* Scaphiocrinus crineus

Poteriocrinus pleias *see* Decadocrinus pleias

SCAPHIOCRINUS Hall

S c a p h i o c r i n u s (P o t e r i o c r i n u s) a e g i n a *see* Decadocrinus aegina

Scaphiocrinus crineus Hall (sp.)

6137 $\frac{4510}{1}$ TYPE P o t e r i o c r i n u s c r i n e u s Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.56.

Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig. 6, 7.

Waverly beds Richfield, Summit co. O.

Scaphiocrinus corycia Hall (sp.)

6138 $\frac{4511}{1}$ [TYPE P o t e r i o c r i n u s c o r y c i a Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.57.

P o t e r i o c r i n u s (S c a p h i o c r i n u s ?) c o r y c i a Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.9.

Waverly beds Richfield O.

C. A. White, coll. 1861

S c a p h i o c r i n u s (P o t e r i o c r i n u s) l y r i o p e *see* Decadocrinus lyriope

S c a p h i o c r i n u s s u b t o r t u o s u s *see* Decadocrinus subtortuosus

Scaphiocrinus subcarinatus Hall

6139 $\frac{4512}{1}$ TYPE S c a p h i o c r i n u s s u b c a r i n a t u s Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.58.

Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.13.

Waverly beds Richfield O.

6140 $\frac{4512}{2}$ TYPE Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.14.

Waverly beds Richfield O.

C. A. White, coll. 1861

TAXOCRINUS Phillips

Taxocrinus communis Hall (sp.)

6141 $\frac{4550}{1}$ TYPE F o r b e s i o c r i n u s c o m m u n i s Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.55.

Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.3.
Waverly beds Richfield O.
C. A. White, coll. 1861

6142 $\frac{4560}{2}$ TYPE Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.4.
Waverly beds Richfield O.
C. A. White, coll. 1861

6143 $\frac{4560}{3}$ TYPE Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.5.
Waverly beds Richfield O.

Taxocrinus kelloggi Hall (sp.)

6144 $\frac{4561}{1}$ TYPE Forbesiocrinus kelloggi Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.56.
Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.1.
Waverly beds Richfield O.

Taxocrinus tardus Hall (sp.)

6145 $\frac{4562}{1}$ TYPE Forbesiocrinus lobatus var. tardus Hall. 17th annual report of the New York state cabinet of natural history. 1864. p.56.
Forbesiocrinus tardus Hall & Whitfield. Geological survey of Ohio. 1875. v.2, pt 2, pl.12, fig.2.
Waverly beds Richfield O.
C. A. White, coll. 1861

On slab with type of Decadocrinus subtortuosus, pl.12, fig.15, 16.

Zeacrinus merope *see* Pachylocrinus merope

Zeacrinus paternus *see* Pachylocrinus paternus

BRACHIOPODA

SCHIZAMBON Walcott

Schizambon duplicimuratus Hudson

6146 $\frac{8262}{1}$ TYPE Schizambon duplicimuratus Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.284, pl.5, fig.6.

Middle Chazy limestone
Sloop cove, Valcour island, Lake Champlain, N. Y.
G. H. Hudson, donor

6147 $\frac{8262}{2}$ TYPE Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.5, fig.7.
Middle Chazy limestone
Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

SYNTROPHIA Hall & Clarke

Syntrophia multicosta Hudson

6148 $\frac{8452}{1}$ TYPE Syntrophia multicosta Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.285, pl.5, fig. 8-10, 14.
Middle Chazy limestone
Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

6149 $\frac{8452}{2}$ TYPE Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.5, fig.11, 12.
Middle Chazy limestone
Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

6150 $\frac{8452}{3}$ TYPE Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.5, fig.13.
Middle Chazy limestone
Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

6151 $\frac{8452}{4}$ TYPE Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.5, fig.15.
Middle Chazy limestone
Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

LAMELLIBRANCHIATA

BUCHIOLA Barrande

Buchiola halli Clarke

5024 $\frac{9080}{4}$ = TYPE Glyptocardia speciosa Hall. Paleontology of New York. 1885. v.5, pt 1, pl.80, fig.10.
$\frac{9085}{2}$

Buchiola halli Clarke. New York state museum memoir 6. 1903. p.301.

Hamilton shale

Near Norton's landing, Cayuga lake, N. Y.
H. H. Smith, coll. 1871

CYRTODONTA Billings

Cyrtodonta? lamellosa Hudson

6152 $\frac{9171}{1}$ TYPE Cyrtodonta? lamellosa Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.287, pl.4, fig.10-13.

Middle Chazy limestone

Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

Glyptocardia speciosa *see* Buchiola halli

MODIOLOPSIS Hall

Modiolopsis subquadrilateralis Hudson

6153 $\frac{9505}{1}$ TYPE Modiolopsis subquadrilateralis Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.286, pl.4, fig.8, 9.

Middle Chazy limestone

Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

NUCULITES Conrad

Nuculites barretti Shimer

6154 $\frac{9584}{1}$ TYPE Nuculites barretti Shimer. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.261, fig.9.

Oriskanian Trilobite mountain, Orange co. N. Y.
H. W. Shimer, donor

6155 $\frac{9584}{2}$ TYPE Shimer. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.261, fig.10.
Oriskanian Trilobite mountain, N. Y.
H. W. Shimer, donor

GASTROPODA

EUNEMA Salter

Eunema epitome Hudson

6156 $\frac{10126}{1}$ TYPE Eunema epitome Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.290, pl.4, fig.6, 7.
Middle Chazy limestone
Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

Eunema historicum Hudson

6157 $\frac{10127}{1}$ TYPE Eunema historicum Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.288, pl.4, fig.5.
Middle Chazy limestone
Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

HOLOPEA Hall

Holopea microclathrata Hudson

6158 $\frac{10146}{1}$ TYPE Holopea microclathrata Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.294, pl.4, fig.3, 4.
Middle Chazy limestone
Sloop cove, Valcour island, N. Y.
G. H. Hudson, donor

CEPHALOPODA

CAMEROCERAS Conrad

Cameroceras (Proterocameroceras) brainerdi Whitfield (sp.)

6159 $\frac{12084}{1}$ HYPOTYPE Orthoceras brainerdi Whitfield. American museum of natural history bulletin. 1886. v.1, no.8, p.319.
Cameroceras (Proterocameroceras) brainerdi Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.6, fig.1.

Beekmantown limestone
Valcour, Clinton co. N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6160 12084/2 **HYPOTYPE** Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.6, fig.2.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6161 12084/3 **HYPOTYPE** Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.6, fig.3.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6162 12084/4 **HYPOTYPE** Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.7, fig.1-10.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6163 12084/5 **HYPOTYPE** Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.8, fig.1.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6164 12084/6 **HYPOTYPE** Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.8, fig.2.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6165 12084/7 **HYPOTYPE** Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.8, fig.3, 6.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6166 12084/8 **HYPOTYPE** Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.8, fig.4.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6167 12084/9 **HYPOTYPE** Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.8, fig.5.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6168 $\frac{12084}{10}$ HYPOTYPE Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.8, fig.7, 8.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6169 $\frac{12084}{11}$ HYPOTYPE Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.9, fig.1.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6170 $\frac{12084}{12}$ HYPOTYPE Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.9, fig.2.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

Orthoceras brainerdi *see* Cameroceras (Proterocameroceras) brainerdi

PILOCERAS Salter

Piloceras explanator Whitfield

6171 $\frac{12470}{1}$ HYPOTYPE Piloceras explanator Whitfield. American museum of natural history bulletin. 1886. v.1, no.8, p.323.
Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist 1904. pl.9, fig.3.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6172 $\frac{12470}{2}$ HYPOTYPE Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.10, fig.1; pl.11, fig.1-7; pl.12, fig.1-4; pl.13, fig.1, 2.
Beekmantown limestone Fort Cassin Vt.
C. Rominger, coll. 1888

6173 $\frac{12470}{3}$ HYPOTYPE Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.12, fig.5.
Beekmantown limestone Valcour N. Y.
G. van Ingen and R. Ruedemann, coll. 1899

6174 $\frac{12470}{4}$ HYPOTYPE Ruedemann. New York state museum bulletin 80; annual report of the state paleontologist. 1904. pl.13, fig.3–5.
Beekmantown limestone Fort Cassin Vt.
C. Rominger, coll. 1888

CRUSTACEA

CHEIRURUS Beyrich

Cheirurus mars Hudson

6175 $\frac{13250}{1}$ TYPE Cheirurus mars Hudson. New York state museum bulletin 80; annual report of the state paleontologist. 1904. p.295, pl.5, fig.1, 2.

Middle Chazy limestone Sloop cove, Valcour island, Lake Champlain, N. Y.

G. H. Hudson, donor

CLASSIFICATION OF TYPE SPECIMENS BY GEOLOGIC FORMATIONS

References are to the serial marginal numbers at the left of each page.

LOWER SILURIC

BEEKMANTOWN LIMESTONE

Cnidaria

Bryograptus lapworthi, 5758–69
Bryograptus pusillus, 5770
Callograptus *cf.* diffusus, 5771, 5772
Callograptus salteri, 5773–76
Caryocaris *cf.* curvilineatus, 5777
Climacograptus? (Cryptograptus) antennarius, 5778–83
Climacograptus pungens, 5784-90
Dawsonia monodon, 5791-95
Dawsonia tridens, 5796-98
Dendrograptus flexuosus, 5799-5801
Dendrograptus fluitans, 5802
Dendrograptus ? succulentus, 5803-6
Desmograptus cancellatus, 5807-10
Desmograptus intricatus, 5811-15
Dichograptus octobrachiatus, 5816-24
Dictyonema flabelliforme, 5825-47
Dictyonema flabelliforme *var.* confertum, 5848
Dictyonema furciferum, 5849
Dictyonema rectilineatum, 5850,5851
Didymograptus *sp.*, 5852
Didymograptus acutidens, 5853
Didymograptus bifidus, 5854-57
Didymograptus (Isograptus) caduceus, 5858, 5859
Didymograptus caduceus *mut.* nanus, 5860-62
Didymograptus cuspidatus, 5863
Didymograptus ellesi, 5864-66
Didymograptus extensus, 5867-73
Didymograptus filiformis, 5874-80
Didymograptus forcipiformis, 5881-84
Didymograptus gracilis, 4881, 5885-88
Didymograptus incertus, 5889
Didymograptus nanus, 5890-91
Didymograptus nicholsoni *var.* planus, 5892-96
Didymograptus nitidus, 5897-5904
Didymograptus nitidus *var.* grandis, 5905
Didymograptus patulus, 5906-8
Didymograptus similis, 5909-14
Didymograptus spinosus, 5915-17
Didymograptus törnquisti, 5918
Diplograptus dentatus, 5919-23
Diplograptus inutilis, 5924, 5925
Diplograptus laxus, 5926-32
Diplograptus longicaudatus, 5933
Glossograptus echinatus, 5934-36
Glossograptus hystrix, 5937-39
Goniograptus geometricus, 5940-56
Goniograptus perflexilis, 4879, 5957-66
Goniograptus thureaui *var.* postremus, 4923-33, 5967-71
Loganograptus logani, 5972-74
Loganograptus logani *mut.* pertenuis, 5975
Phyllograptus angustifolius, 5976-80
Phyllograptus anna, 5981-85
Phyllograptus anna *mut.* ultimus, 5986-88
Phyllograptus ilicifolius, 5989-96
Phyllograptus typus, 5997-5999
Ptilograptus geinitzianus, 6000
Ptilograptus plumosus, 6001
Ptilograptus tenuissimus, 6002
Retiograptus tentaculatus, 6003-5
Sigmagraptus praecursor, 6006-7
Staurograptus dichotomus, 6008-27
Staurograptus dichotomus *var.* apertus, 6028-31
Strophograptus trichomanes, 6032, 6033
Temnograptus noveboracensis, 6034-41

Tetragraptus amii, 6042-44
Tetragraptus clarkei, 6045-49
Tetragraptus fruticosus, 6050-62
Tetragraptus (Etagraptus) lentus, 6063, 6064
Tetragraptus pendens, 6065-69
Tetragraptus pygmaeus, 6070-73
Tetragraptus quadribrachiatus, 6074-78
Tetragraptus serra, 6079-81
Tetragraptus similis, 6082-93
Tetragraptus taraxacum, 6094-102
Tetragraptus woodi, 6103-5
Trigonograptus ensiformis, 6106-14

Cephalopoda

Cameroceras (Proterocameroceras) brainerdi, 6159-70
Piloceras explanator, 6171-74

CHAZY LIMESTONE

Echinodermata

Malocystites emmonsi, 6129-31

Brachiopoda

Schizambon duplicimuratus, 6146, 6147
Syntrophia multicosta, 6148-51

Lamellibranchiata

Cyrtodonta? lamellosa, 6152
Modiolopsis subquadrilateralis, 6153

Gastropoda

Eunema epitome, 6156
Eunema historicum, 6157
Holopea microclathrata, 6158

Crustacea

Cheirurus mars, 6175

LOWER DEVONIC

ORISKANIAN

Lamellibranchiata

Nuculites barretti, 6154, 6155

MIDDLE DEVONIC

ONONDAGA LIMESTONE

Echinodermata

Dolatocrinus speciosus, 6128

HAMILTON BEDS

Echinodermata

Dolatocrinus glyptus *var.* intermedius, 6126
Dolatocrinus liratus *var.* multiliratus, 6127

Lamellibranchiata

Buchiola halli, 5024

LOWER CARBONIC

WAVERLY BEDS

Echinodermata

Actinocrinus daphne, 6115
Amphoracrinus viminalis, 6116, 6117
Aorocrinus eris, 6118
Aorocrinus helice, 6119, 6120
Decadocrinus aegina, 6121, 6122
Decadocrinus lyriope, 6123
Decadocrinus pleias, 6124
Decadocrinus subtortuosus, 6125
Pachylocrinus merope, 6132
Pachylocrinus paternus, 6133
Platycrinus contritus, 6134
Platycrinus graphicus, 6135
Platycrinus richfieldensis, 6136
Scaphiocrinus crineus, 6137
Scaphiocrinus corycia, 6138
Scaphiocrinus subcarinatus, 6139, 6140
Taxocrinus communis, 6141-43
Taxocrinus kelloggi, 6144
Taxocrinus tardus, 6145

LIST OF TYPE SPECIMENS OF TERTIARY FOSSILS FROM THE PEBAS ON THE MARANHAO RIVER, BRAZIL

DESCRIBED BY T. A. CONRAD IN THE AMERICAN JOURNAL OF CONCHOLOGY 1871

These fossils were obtained on the expedition to Brazil made by the late Professor James Orton and seem to have been collected by Mr Hauxwell of his company. There is no record of how or when they came into the possession of the State Museum

BULIMUS Scopoli

Bulimus linteus Conrad

1 TYPE Bulimus linteus Conrad. American journal of conchology. 1871. 6: 195, pl.10, fig.9.
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

DYRIS Conrad

Dyris gracilis Conrad

2 TYPE Dyris gracilis Conrad. American journal of conchology. 1871. 6:195, pl.10, fig.8; pl.11, fig.7.
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

EBORA Conrad

Ebora (Nesis) bella Conrad

3 TYPE Ebora (Nesis) bella Conrad. American journal of conchology. 1871. 6:194, pl.10, fig.17a, b.
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

Ebora crassilabra Conrad

4 TYPE Ebora crassilabra Conrad. American journal of conchology. 1871. 6:194, pl.10, fig.14.
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

HEMISINUS Swainson

Hemisinus sulcatus Conrad

5 TYPE Hemisinus sulcatus Conrad. American journal of conchology. 1871. 6:194, pl.10, fig.2.
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

ISAEA Conrad

Isaea lintea Conrad

6 TYPE Isaea lintea Conrad. American journal of conchology. 1871. 6:193, pl.10, fig.6.
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

Isaea ortoni Gabb (sp.)

7 HYPOTYPE Mesalia ortoni Gabb. American journal of conchology. 1868. 4:198.

Isaea ortoni Conrad. American journal of conchology. 1871. v.6, pl.10, fig.10.

Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

8 HYPOTYPE Conrad. American journal of conchology. 1871. v.6, pl.10, fig.13.

Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

LIRIS Conrad

Liris laqueata Conrad

9 TYPE Liris laqueata Conrad. American journal of conchology. 1871. 6:194, pl.10, fig.3.

Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

NERITINA Lamarck

Neritina ortoni Conrad

10 TYPE Neritina pupa Gabb. American journal of conchology. 1868. 4:197.

Neritina ortoni Conrad. American journal of conchology. 1871. v.6, pl.10, fig.5.

Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

11 TYPE Conrad. American journal of conchology. 1871. v.6, pl.10, fig.11.

Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

PACHYDON Gabb

Pachydon altus Conrad

12 TYPE Pachydon altus Conrad. American journal of conchology. 1871. 6:197, pl.11, fig.1a, b.

Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

Pachydon carinatus Conrad

13 TYPE Pachydon carinatus Conrad. American journal of conchology. 1871 6:196, pl.10, fig.7.

Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

Pachydon cuneatus Conrad

14 TYPE Pachydon cuneatus Conrad. American journal of conchology. 1871. 6:197, pl.10, fig.12a, b (2 specimens).
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

Pachydon erectus Conrad

15 TYPE Pachydon erectum Conrad. American journal of conchology. 1871. 6:197, pl.10, fig.16.
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

Pachydon obliquus Gabb

16 HYPOTYPE Pachydon obliquus Gabb. American journal of conchology. 1868. 4:199.
Conrad. American journal of conchology. 1871. v.6, pl.10, fig.15.
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

Pachydon ovatus Conrad

17 TYPE Pachydon ovatus Conrad. American journal of conchology. 1871. 6:197, pl.10, fig.4.
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

18 TYPE Conrad. American journal of conchology. 1871. 6:197, type of description.
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

Pachydon tenuis Gabb

19 HYPOTYPE Pachydon tenua Gabb. American journal of conchology. 1868. 4:199.
Pachydon tenuis Conrad. American journal of conchology. 1871. 6:196, pl.10, fig.1a, b.
Tertiary (Pebas group) Pichua, Upper Amazon
Mr Hauxwell, coll.

Bivalve allied to **Mulleria**

20 TYPE Bivalve allied to Mulleria Conrad. American journal of conchology. 1871. 6:192 (mentioned; 2 specimens).
Tertiary (Pebas group) Pichua, Upper Amazon
Mr. Hauxwell, coll.

INDEX

The superior figures tell the exact place on the page in ninths; e. g. 18^3 means page 18, beginning in the third ninth of the page, i. e. about one third of the way down.

Accessions to collections, 39^7–54^9.
Aquatic insects, 34^8.
Archeology, report on, 36^6; accessions to collection, 44^2–45^9.
Arey, A. L., acknowledgments to, 14^8.

Beauchamp, William M., archeological work, 36^6.
Beekmantown limestone, faunas, 23^2.
Binns, Charles F., assistance from, 26^2.
Birds, 36^5.
Bishop, I. P., preparation of map of Buffalo quadrangle, 14^4.
Botany, report on, 33^4–34^2; accessions to collection, 46^1–49^5.
Brazil, *see* Maranhao river.
Buffalo quadrangle, 14^4.
Building, need of new, 39^2.
Building stones, fire tests, 25^4–26^1.
Burnham, Stewart H., work of, 34^2.

Champlain valley, geology, 18^6–19^6.
Chazy limestone, faunas, 23^2.
Clay-working and ceramics, state school of, 26^2.
Cobleskill formation, 15^6–16^7.
Collections, accessions to, 39^7–54^9.
Conrad, T.A., List of Type Specimens of Tertiary Fossils from the Pebas on the Maranhao River, Brazil, 131^1–33^9.
Correlation studies, 17^5–18^5.
Cushing, H. P., work of, 12^7.

Devonic, early, of eastern America, 17^5–18^3.
Devonic crinoids, 24^7–25^2.
Devonic fishes, 23^7–24^2.

Eastman, C. R., study of Devonic fishes, 23^7.
Eaton, E. H., publication on birds, 36^5.
Economic geology, 21^8–22^8, 25^4–26^3.
Entomology, report on, 34^3–35^9; contributions to collection, 49^5–54^9.

Fairchild, H. L., acknowledgments to, 14^8; work of, 19^9.
Feldspar, 22^1.
Field work, 12^6–22^8.
Fossil plants, 24^2.
Fossils, new entries on general record of localities, 55^1–57^9; list of type specimens, 58^1–130^9.

Geographic geology, 18^6–21^5.
Geology, work in, 12^2; accessions to collection, 39^9–40^6. *See also* Economic geology.
Glacial drainage in Western New York, 19^9–21^5.
Goldman, M. F., work of, 17^3.
Grabau, A. W., preparation of map of geology of the Schoharie region, 15^2.
Grape root worm, 34^7.
Graphite deposits, 22^4.
Graptolites, memoir on, 23^5.
Guelph fauna, 18^3.

Hammondsport quadrangle, 14^5.
Hartnagel, C. A., preparation of map of Rochester quadrangle, 14^8; investigations on Cobleskill formation, 15^6.
Hemiptera, 34^9–35^1.
Hindshaw, H. H., study of marble quarries, 21^9; investigations on feldspar, 22^1.
Hudson valley, geology, 18^6–19^6.
Hydrology, 21^6.

Iron ores, 22^5.

Kaolin, 22^3.
Kirk, Edwi , work on Devonic crinoids, 24^9.

Leaf-hoppers, 34^8.
Localities of fossils, new entries on general record of, 55^1–57^9.
Long lake quadrangle, geology of, 12^7–13^8.

Louisiana Purchase Exposition, 21[8]; catalogue of exhibits and exhibitors, 26[4]–33[1]; entomologic exhibit, 35[5].
Luther, D. D., maps prepared by, 14[4], 14[6]; work on publications, 25[3].

Maps, stratigraphic, 13[3]–14[4].
Maranhao river, Brazil, list of type specimens of Tertiary fossils from the Pebas on, 131[1]–33[9].
Marble quarries in St. Lawrence county, study of, 21[9]–22[1].
Mineralogy, report on, 33[2]; accessions to collection, 41[3]–43[1].
Mosquitos, 34[3].
Museum collections, condition and distribution, 38[1]–54[9].

Needham, James G., study of stone flies or Plecoptera, 34[8].
New York State Museum, development, 5[3]–9[9].

Office work, 22[9]–26[8].
Osborn, Herbert, work of, 34[9].

Paleontology, work in, 12[2]; report on, 23[2]–25[2]; accessions to collection, 40[6]–41[3].
Peat deposits, 22[2].
Penn Yan quadrangle, 14[5].
Postglacial drainage in western New York, 19[9]–21[5].
Postglacial faults, 19[6].
Potsdam sandstone, outcrops, 22[7].
Precambric geology, field work, 12[6]–22[8].
Publications, 36[9]–37[9].

Rafter, George W., report on hydrology of New York, 21[6].
Ries, Heinrich, investigations on building stones, 25[4].
Rochester quadrangle, 14[8].
Ruedemann, Rudolf, investigations, 23[2]; memoir on graptolites, 23[5]; listing of type specimens of fossils, 23[6].

San José scale, 34[5].
Sandstone, 22[7].
Schoharie region, geology of, 15[2].
Science Division, permanent staff, 10[1]–11[9].
Shawangunk conglomerate, 16[8]–17[2].
Stratigraphic work, preparation for publication, 25[3].

Tertiary fossils, list of type specimens from the Pebas on the Maranhao river, Brazil, 131[1]–33[9].
Tully quadrangle, 14[9]–15[1].
Type specimens of fossils, list of, 23[6], 58[1]–130[9].
Type specimens of Tertiary fossils from the Pebas on the Maranhao river, Brazil, 131[1]–33[9].

Van Duzee, E. P., work of, 34[9].

Watertown region, stratigraphy of, 17[2].
White, David, study of fossil plants, 24[2].
Woodworth, J. B., work of, 18[6].

Zoology, report on, 36[1]; accessions to collection, 43[2]–44[1].

Appendix 1

Geology 7-10

Museum bulletins 83, 84, 95, 96

7 Pleistocene Geology of the Mooers Quadrangle

8 Ancient Water Levels of the Champlain and Hudson Valleys

9 Geology of the Northern Adirondack Region

10 Geology of the Paradox Lake Quadrangle

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JOHN M. CLARKE Director

Bulletin 83

GEOLOGY 7

PLEISTOCENE GEOLOGY OF MOOERS QUADRANGLE

BEING A PORTION OF CLINTON COUNTY, INCLUDING PARTS OF THE TOWNS OF MOOERS, CHAMPLAIN, ALTONA, CHAZY, DANNEMORA AND BEEKMANTOWN N. Y.

BY

JAY BACKUS WOODWORTH

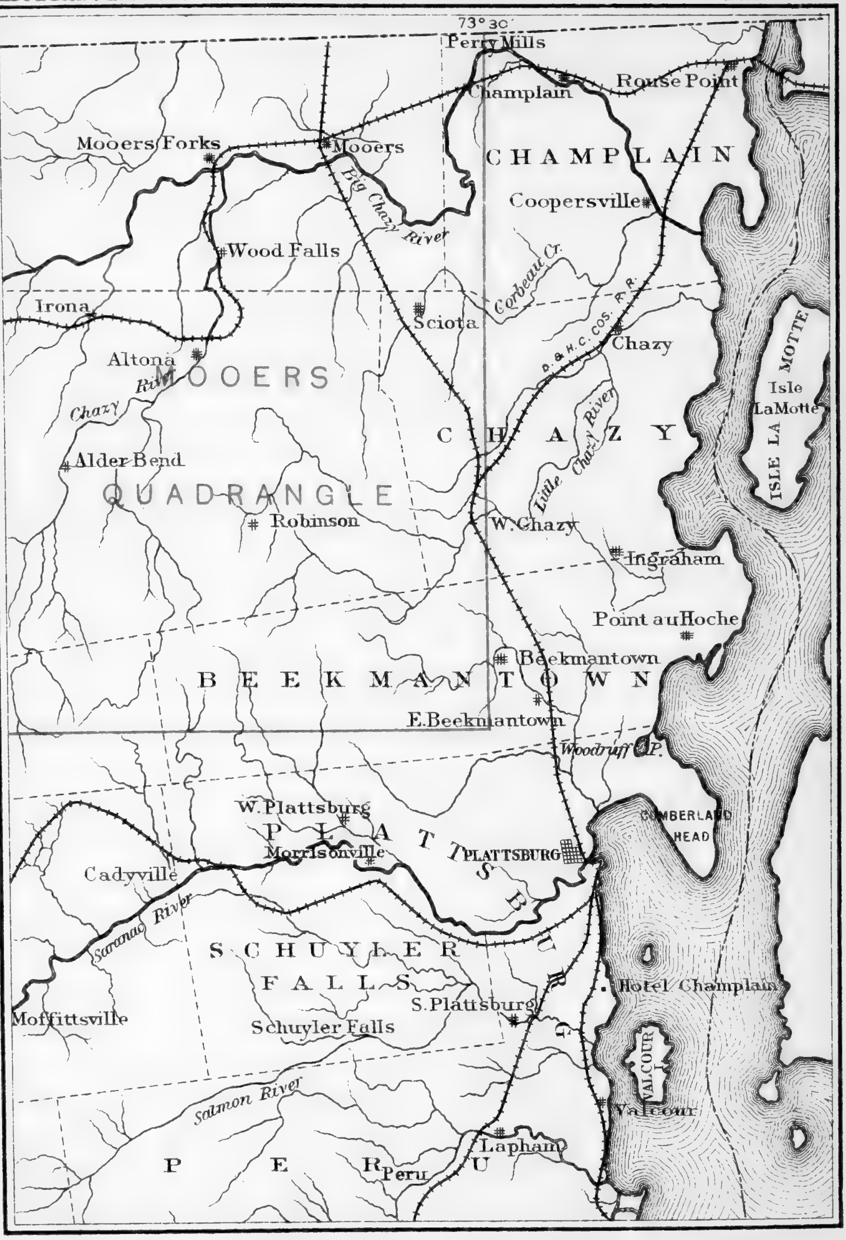
	PAGE
Preface	3
Introduction	4
Surface deposits of the area	4
Wisconsin epoch	5
Glacial striation	5
Table of glacial striae	5
Interpretation of the striae	6
Glacial erosion	8
Glacial deposits	9
Glacial drainage and spillways	13
Ingraham esker	13
Deltas contemporaneous with ice fronts	14
Spillways and the flat rocks	16
Small rock exposures	24
Late and Post-Wisconsin lake and marine deposits	25
Shore lines of the area	26
Marine invasion	46
Recent changes	50
Streams and stream deposits	50
Wind-blown sands	52
Swamps	52
Summary of Pleistocene history of the area	53
Explanation of the map	55
Bibliography	57
Index	59

Plates FACE PAGE

1 Index map showing location of Mooers quadrangle ... 3
2 Sketch map of Mooers quadrangle ... 11
3 Frontal moraine ridges north of Altona spillway ... 11
4 The Ingraham esker ... 13
5 Sketch map of spillways from the Canada line to the Little Chazy river ... 18
6 Altona "flat rock" spillway ... 18
7 The Dead Sea; view from head of gorge ... 19
8 The Dead Sea, looking s. 76° w ... 19
9 View from western end of Dead Sea, showing Potsdam sandstone and high-water mark ... 19
10 View near Dead Sea, looking north over the washed ledges of Potsdam sandstone ... 19
11 Sketch map of Covey hill, Canada ... 22
12 Looking north along eastern slope of Cobblestone hill ... 33
13 A lower beach than in plate 12 ... 33
14 Crest of Cobblestone hill, showing strong wave action on boulders and large cobbles ... 33
15 The beach at 500 feet elevation in Mooers ... 39
16 Looking west by north on the shore bar at 500 feet, on the head waters of Bullis brook ... 39
17 Shore bar cut through by head waters of Bullis brook ... 39
18 Looking north along the uppermost beach ridge shown in plate 19 ... 46
19 Looking east over the coarse beach ridges along the shore south of the Sciota cliff ... 46
20 Landward slope of one of the coarse beaches, 2½ miles south of Sciota ... 46
21 Looking north along the less developed beach lines south of Sciota ... 46
22 Abandoned sea cliff in Potsdam sandstone ... 46
23 Upper part of the old cliff south of Sciota shown in plate 22 ... 46
24 Looking south along abandoned sea cliff in Potsdam sandstone ... 46
25 Sketch map of Mooers quadrangle showing extent of submergence beneath the sea ... 47

COVER PAGE

Geologic map of Mooers quadrangle ... 3



INDEX MAP SHOWING LOCATION OF MOOERS QUADRANGLE

SCALE OF MILES:

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New York State Museum

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Bulletin 83

GEOLOGY 7

PLEISTOCENE GEOLOGY OF MOOERS QUADRANGLE

BEING A PORTION OF CLINTON COUNTY, INCLUDING PARTS OF THE TOWNS OF MOOERS, CHAMPLAIN, ALTONA, CHAZY, DANNEMORA, AND BEEKMANTOWN N. Y.

PREFACE

In 1900 Prof. J. B. Woodworth, of Harvard University, was requested by my predecessor in office, Dr F. J. H. Merrill, to take up a study of the problems of Pleistocene submergence in the Hudson river valley. As a first step, a careful detailed survey was made of the Hempstead and Oyster Bay quadrangles, the results of which were published in Bulletin 48 of the New York State Museum; then an extended reconnaissance of the valleys of the Hudson river and Lake Champlain was undertaken for the purpose of determining the nature and extent of the evidences of marine transgression, this reconnaissance being extended as far north as Montreal with the purpose of correlating the marine beaches there with those which had been recognized in Essex county. This reconnaissance in considerable detail was continued through the seasons of 1901 and 1902, after which it became evident that it was important to make a complete survey of some specific area where there was an abundance of phenomena bearing on the matter under investigation. Accordingly, during the field season of 1903, a complete study was made of the area of the Mooers quadrangle situated in northern Clinton county on the Canadian border. The detailed results of this work, illustrated by a geologic map, are given in the following bulletin.

JOHN M. CLARKE

State Geologist

INTRODUCTION

The Mooers quadrangle includes an area of about 225 square miles covering a part of the northeasternmost spur of the Adirondacks and the gravelly and sandy lowlands west of Lake Champlain. The international boundary line between New York and the Dominion of Canada forms the northern limit of the map [pl. 1].

The geologic description of the hard rocks of this area has already been given in a bulletin of the Museum by Professor Cushing. In this and earlier reports published under the auspices of the Natural History Survey of the State, brief references are made to the glacial and postglacial deposits which in this district occur along the margins of Lake Champlain. In the appendix to this paper will be found a list of the principal references, a number of which are quoted in the text.

The Pleistocene geology of this area is of peculiar interest because of the submergence of the Lake Champlain district beneath the sea in the closing stage of the Pleistocene period. The detailed study of the area was undertaken for the purpose of obtaining a more complete and accurate knowledge of the shore lines of this epoch of marine submergence than could be gained by the rapid reconnaissance conducted by the writer in reference to the same problem in the major portion of the valleys of the Hudson and Lake Champlain.

It is necessary to state here that the author found, on selecting this area for examination, that he had been preceded in the same quest by Dr G. K. Gilbert, of the United States Geological Survey. Through Dr Merrill, state geologist, Dr Gilbert very generously offered his field notes for such use as could be made of them, not only for the Mooers district but also for the northern flank of the Adirondacks as far west as Lake Ontario. These notes have been used first as guides for localities to be visited and secondly as important checks on the observations and conclusions of the writer, who wishes here to express his great indebtedness to Dr Gilbert.

SURFACE DEPOSITS OF THE AREA

The surficial or loose deposits of the Mooers quadrangle so far as known, pertain altogether to the Pleistocene period or to more recent accumulations which are still in progress. For the most

part, these deposits are glacial drift, either very much as left by the retreating ice sheet, in the uplands above 600 feet, or, below that level, more or less rearranged by wave and current action on the bottom of temporary ice-barred lakes or at yet lower levels by the sea. The strictly glacial deposits are also the most recent of the glacial period and are presumably to be classed as of the Wisconsin ice epoch and as pertaining to the later portion of that time.

WISCONSIN EPOCH

The drift of this epoch forms the surficial deposits in the southwestern part of the quadrangle and is almost everywhere present in an unmodified form above the 600 foot level, though, in consequence of processes which will be described later, much modification of the drift has taken place at levels from near 900 feet downward.

The glacial origin of this material is shown by numerous glacial striae on the rock surfaces and by the direction in which it has been transported, as well as by the occurrence of characteristic recessional moraines.

Glacial striation

The direction and grouping of the glacial striae on this area, indicating the direction in which the ice moved across it, are shown on the accompanying map by arrows for particular localities at which the striae may be seen and by the pattern employed on the map for the ice-laid drift over the areas occupied by this material.[2] It will be noted that along the western border of the area the ice moved in a southwesterly direction, and that along the southern border it moved in a southerly direction.

The accompanying table of observed striae includes those noted in the field seasons of 1902-3.

Table of glacial striae

s. 61° w.	Covey hill, Can.; in road gutter on top of hill
s. 46° w.	Mooers; in public road, 3.1 miles n. of Irona railroad crossing
s. 36° w.[1]	Mooers; s. bank of Big Chazy near camp meeting grounds above Mooers
s. 56° w.	Altona; on sandstone ledges in woods s. of railroad, 2¼ miles w. of Irona, possibly off map
s. 56° w.	Altona; on old military road, ¾ mile e. of western edge of map
s. 46° w.	Mooers; on road, ¼ mile w. of Big Chazy at Wood Falls

[1] Locality farther east than others in this part of the table, where the ice moved more southerly.

[2] This latter plan has not been carried out.

s. 38° w.	Mooers; faint striae, on sandstone, ½ mile s. e. from Wood Falls on wood road
s. 31° w.	Altona; on Potsdam about 1 mile w. of "Rattlesnake den"
s. 21° w.	Altona; s. of bend in public road, 1¾ miles e. of Alder Bend
s. 9° w.	Altona; s. of e.–w. road, 1¾ miles n. by e. from Purdy Mill on sandstone
s. 10° e.	Altona; on red sandstone in road gutter s. of Purdy Mill
s. 31° w.	Altona; n. slope of Pine ridge 1.1 m. n. n. e. of Dead Sea
s. 26° w.	Altona; on Potsdam sandstone by schoolhouse 3⅗ miles due e. from Altona
s. 30° w.	Altona; in road gutter on grit, near brook just s. w. of Robinson
s. 1° w.	Beekmantown; on summit of Rand hill by n.–s. road
s. 56° w.	Altona; on old military road, 1¾ miles s. e. of Robinson on red sandstone; also s. 61° w.
s. 1° w.	Altona; on military road 1⅓ miles n. w. from West Beekmantown Corners
s. 2° e.	Altona; in road gutter of flat rock area e. of Corbeau creek, 2½ miles s. by w. from Sciota
s. 4° e.	Chazy; 1¾ miles n. of West Chazy, on road to Sciota

Interpretation of the striae

The localities named in the above table are grouped as nearly as possible as they would be traversed in going from northwest to southeast so as to give readings along a line normal to the direction of ice flow, beginning on the northwest at a locality in Canada about 4 miles beyond the limits of the map, where the striation of the upper St Lawrence valley is well marked.

For the proper understanding of the divergence of the glacial striae toward the south and west in this part of Clinton county, it is necessary to consider the relation of the Adirondack mountain mass and the valleys which surround it to the ice sheet moving southwestward against it from the center of movement in Ungava. The fact that the ice sheet moved in the direction stated approximately along the lines of striation indicated on the accompanying map is attested by several phenomena: first, by the occurrence within this field of erratics derived from the basic eruptive rocks of the chain of paleozoic volcanic stocks which extend from the northern termination of the Green mountains north and westward to and beyond Mt Royal; second, by the character of the ice-worn surfaces southward in the Champlain valley; and third, by the position of moraines and deposits of gravel and sand laid down in temporary lakes held in on the northern slopes of the Adirondacks by a now vanished wall,

which can be explained only by the former presence of an ice front along the flanks of the uplands.

All the facts indicate that the ice moved into northeastern New York in a southwesterly direction. Passing over the St Lawrence plain the ice moved southeastward into northwestern Vermont, and southward into the valley of Lake Champlain, pressing more strongly against the Adirondacks than against the eastern side of the valley. Another part moved southwestward up the St Lawrence valley into the basin of Lake Ontario. As the ice-sheet culminated in thickness and southward extension, it advanced over the outlying spurs of the Adirondacks, such as for instance Dannemora mountain, shown on the Mooers quadrangle. It moved up over the low platform of Potsdam sandstones flanking the Adirondacks on the north, with a southwesterly direction. The eastern margin of this platform forms the belt of higher ground entering the Mooers quadrangle from the northwest and extending through the Flat Rock area of Altona. Over most of this belt the ice moved under the influence of the relief of pressure which was found to the southwestward along the western base of the Adirondacks. On the south and east of this area the ice was drawn into the Champlain flowage. Thus we have in this district the topographic versant on which the ice divided, one tongue going southward to form the Champlain-Hudson glacier and the other southwestward to form the greater St Lawrence glacier. So far as present knowledge goes, it would appear that at the maximum of glaciation the ice passed quite over the Adirondacks, though it must have been in the highest part of that region much slackened in flow as compared with the freer run of the ice through the large valleys on either side.

In the till-covered area of the map, accompanying this report, in which district nearly all the striae were observed, the color representing the till might be made to express by a linear design the approximate direction of striation, and thus the lines along which the till of any particular place presumably has been transported. In such a pattern, of course, where observed striae are relatively infrequent, the lines of flowage must be largely interpreted; and in the southern part of the area, particularly in Dannemora, it may be that the striae when found would deviate somewhat from

the lines as shown on a map. The method of interpretation would consist in distributing the lines of flow between the nearest observed striae as converging or diverging lines projected into parallelism with the nearest observed striae farther downstream. The attempt might be made to bend the lines so as to show how the local irregularities of the topography would ordinarily deflect the ice. In fact, only one station in this area was found in which it was clear that the striation had been thus influenced by local slopes.

It is important to note that, just as the ice moved southwestward across this district, so in the retreat of the ice sheet, its front would be expected to recede from the district as a wall of ice approximately at right angles to the lines of striation. From this may be deduced the probability that the northeastern slopes of the Adirondacks were freed from the Labradorian ice sheet while it still lay against the northern end of the Green mountains. As another probability in consequence of this mode of retreat, a connection would be established between the Lake Ontario basin, the upper St Lawrence and Lake Champlain along the lowlands at the base of the Adirondacks before the lower St Lawrence was open for connection with the Atlantic ocean. Other effects of this mode of retreat of the ice front would be found in the existence of shores of temporary, ice-dammed lakes on the Adirondack side of Lake Champlain, which had no counterpart on the Green mountain side so far north and at so early a time as when the ice was but partly withdrawn from the upper, open mouth of the Champlain valley. It might well thus be found that beaches exist on the west side of the valley at high levels without their counterpart on the east side of the valley. These possible deductions from the striation of the region in relation to local relief are mentioned because, as will later be shown, certain observations lead to the same conclusions.

Glacial erosion

It is difficult to estimate the amount of erosion by the direct action of the ice sheet in this area. The principal streams are obviously not flowing in their preglacial or interglacial channels, for, except where they are intrenched in modern postglacial

gorges, they have shallow beds in the drift coating with here and there bottoms of bed rock, evidently along courses which have been taken since the disappearance of the ice from the uplands and the withdrawal of the bodies of water which submerged the lowlands on the north and east. The earlier channels of these streams, if such exist, have not been discovered.

Glacial deposits

The entire area of this quadrangle appears to have been covered with deposits by the ice sheet; but in more than half of the area the drift has either been removed or worked over by waves and currents to such an extent that at least the upper visible portion of the surface material in the low grounds can hardly be called glacial drift. The unmodified glacial deposits occupy the higher grounds everywhere above the 900 foot level in Altona and the northeastern part of Dannemora and the northwestern part of Beekmantown.

Till of the uplands

In the elevated grounds above the zone of wave action the glacial deposits are mainly unstratified and of the class denominated till or ice-laid drift. The material of this drift is largely the Potsdam sandstone derived from the immediately underlying and adjacent area of these rocks on the north. Angular slabs of the sandstone are almost everywhere met with in the till area. The finer debris between the slabs is also prevailingly of the grayish white gravel or sand from the same rock. But fragments of other rocks, more commonly of igneous origin occur, and evidently have traveled from known outcrops of such rocks in Canada.

The till in the uplands varies much in thickness. A glance at the accompanying map shows by the distribution of outcrops that very slight excavations along certain roads have served to reveal the rock.

In the plateau of sandstone about Alder Bend, the till, so far as can be determined for considerable areas, is probably over 20 feet in thickness, but except in certain restricted belts, where it is heaped up, the till appears to be a relatively thin sheet.

Till of the lowlands

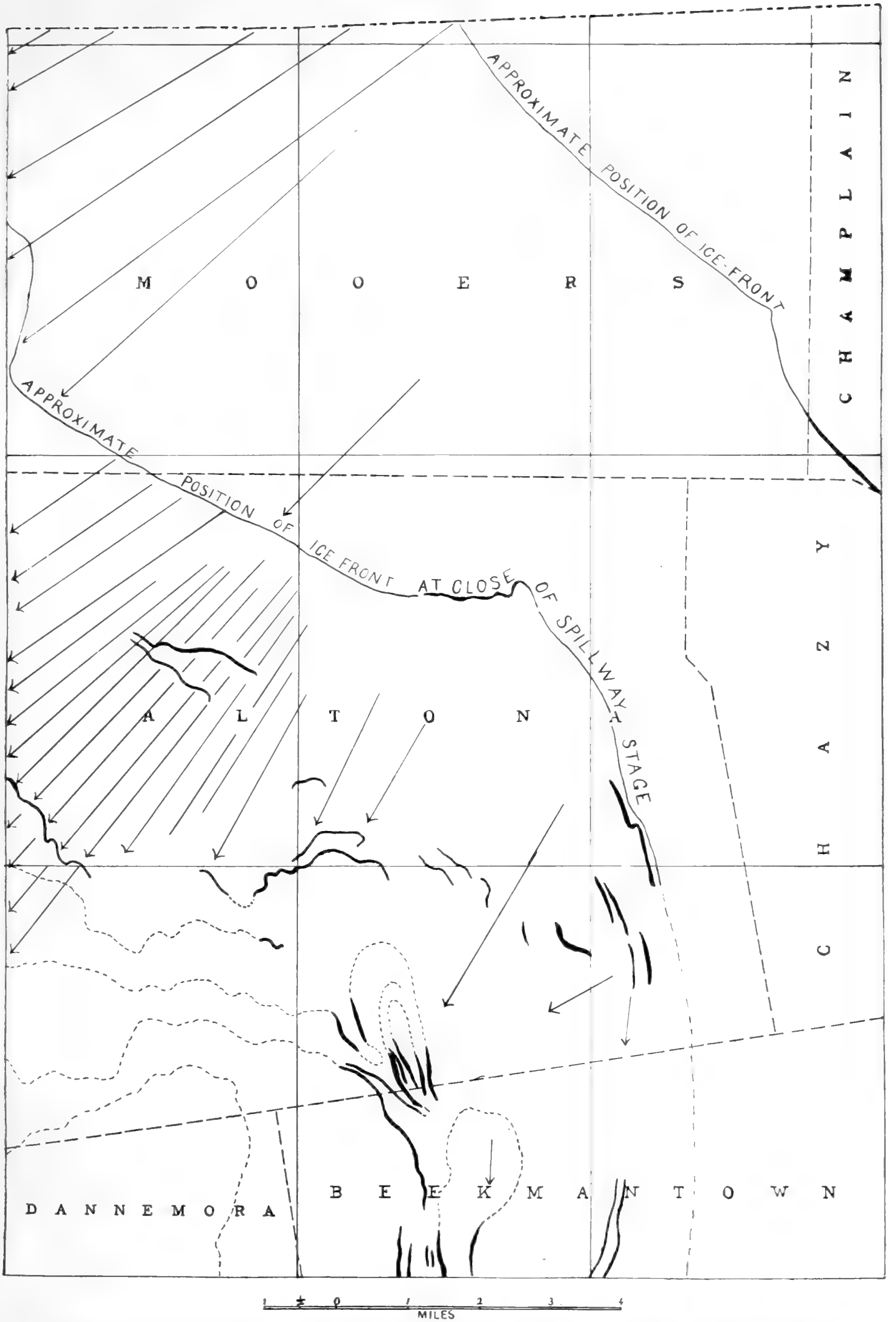
In the low district, below 900 feet in elevation, there are several areas which appear to be distinctly of an ice-laid character; the general distribution of erratics over the surface, and the frequent occurrence of elongated, low hills with wave-washed drift, are evidence that the surface was originally, or at least when the ice sheet disappeared, supplied with an abundant ground moraine of a somewhat diversified relief.

Probable drumlins. In the eastern part of the town of Mooers, there are several low, oval-shaped hills, about half a mile long at the base and extending from east of north to west of south, whose general appearance recalls that of the drumlins of Massachusetts except that the summits and frequently the slopes of these hills are ribbed with beaches or strewn with wave-washed material. These hills lie between the 240 foot level and that of 340 feet, and they rise about 50 feet above the ground at their base. There are three good examples northwest of Mooers Junction, each with beaches on its western slope. The eastern slope of these three hills is decidedly glacial in appearance, strewn with large and small erratics without distinct marks of wave erosion. No cuts have been made in them except for one north of Sperry brook and within a mile of the international boundary where the road cutting on the west slope shows a very thick accumulation of thoroughly rounded waterworn beach pebbles at about 350 feet above present sea level. The eastern slope of these hills appears to be very much as it might have been left by the retreating ice sheet. In a later chapter of this report I shall consider the possibility of the ice front resting against these eastern slopes while waves beat on the western slopes. In the case of the ridge about 1 mile northwest of Thorn the top is wave-heaped, and to the southward both slopes show the wave-assorting of the gravels.

The hills of this class between Mooers and Biddles crossing are wave-marked on the eastern slope and near the crest. The southernmost of the two hills just north of Bullis brook has a decidedly drumlinlike contour.

The major axes of these hills do not coincide with the direction of glacial striation in their vicinity. Their axes lie to the west of south, while the glacial striation, so far as it can be inferred from

Plate 2



Sketch map of Mooers quadrangle showing known frontal moraines (thick lines); approximate ice fronts (thin lines), and probable frontal moraines (broken lines). The arrows indicate direction of glacier motion

Plate 3

Frontal moraine ridges north of the Altona spillway between Altona and Sciota. Looking northeast

scanty observations in the low ground, was in that part of Mooers township between s. w. and s. w. by s.

Frontal and recessional moraines

There are a number of patches of thickened till within the area covered by this map, which have been deposited at or near the ice front in the last stages of the retreat from the State. The accompanying sketch map [pl. 2] shows by heavy black lines the supposed position of the ice front when these deposits were made. The clearest examples occur in the depression between Rand hill and Jericho. The road from Jericho to Sandburn brook skirts the eastern base of a morainal terrace. The southern slope of the 1400 foot hill, from 1½ to 2 miles east of Jericho, is characterized by strong morainal ridges apparently deposited on the margins of local tongues of ice sweeping about the eastern and western slopes of this hill. There are other local patches of hummocky till along Smith Wood brook. The detailed mapping of such deposits in the thick woods in the southwestern corner of the sheet appeared impracticable, and there are probably lines of ice front yet to be traced in the area. A very distinct series of frontal deposits appears to the southeast and southwest from Big hill in Altona. The same deposits probably extend through the vicinity of Alder Bend toward Ellenburg. This line probably is to be associated with the heavy drift deposits about the southeastern base of Rand hill between 700 and 900 feet in elevation, where a few kettle holes and a decidedly marginal moraine topography are well developed.

Frontal moraine ridges [*see* pl. 3] occur at an elevation of about 600 feet, north of Altona and along the road between that village and Sciota, on the eastern and northeastern border of the Flat rock area. Strong morainal ridges, apparently lateral moraines, appear at the southern end of Pine ridge between the 600 foot and 700 foot contour lines and in an *en échelon* arrangement continue along the eastern base of the high ground from Altona into Beekmantown, sometimes much modified by wave action on their eastern slopes. The most conspicuous example of a wave-washed moraine or boulder belt occurs in the ridge just north of the Little Chazy river, where, according to the map, it traverses the 600 foot contour line. This moraine, northward to

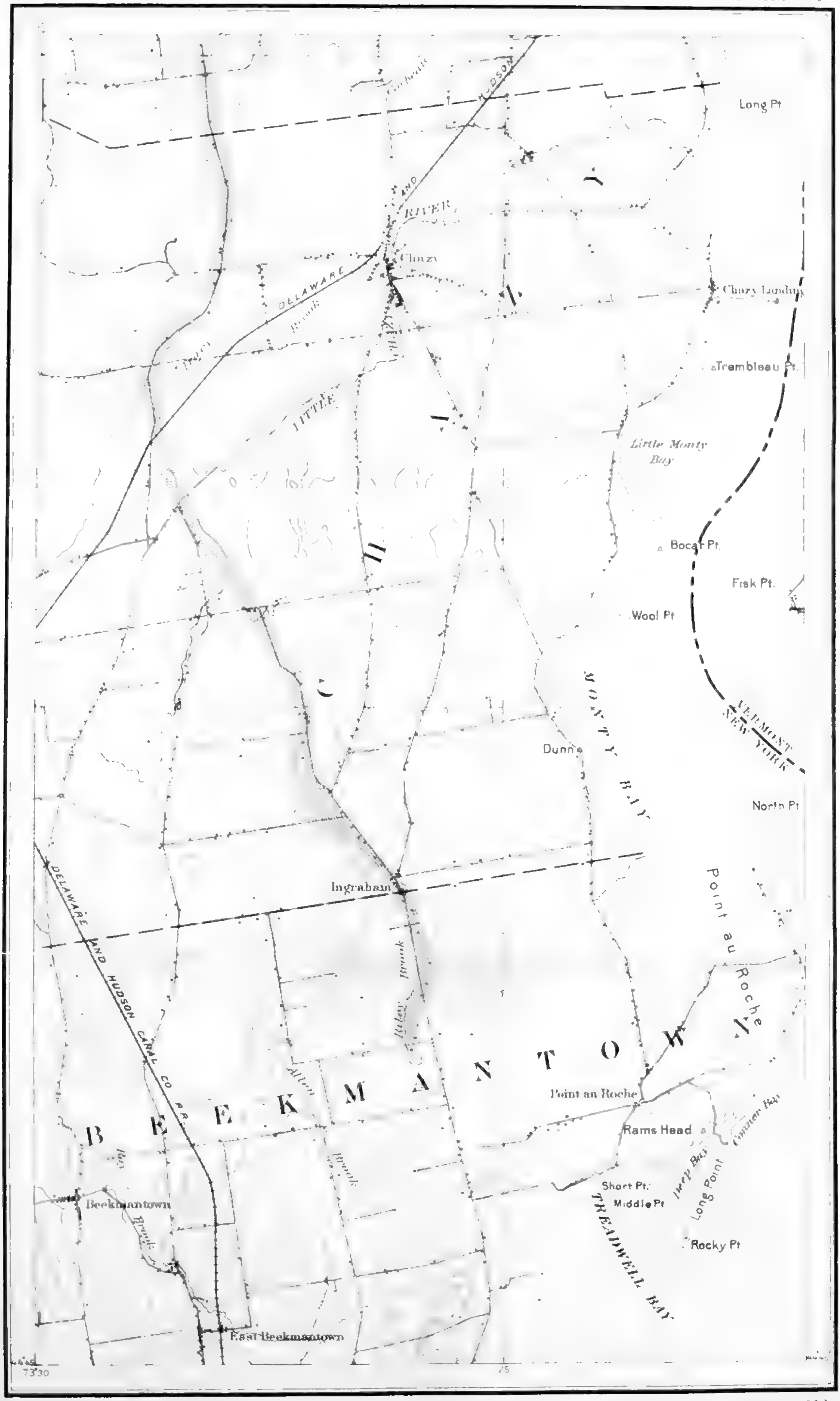
where it is lost on the bare, flat rock, is a pile of blocks mainly of Potsdam sandstone, forming one of the most striking and singular glacial deposits of the northern Adirondack region [pl. 13, showing a photographic view of the eastern, wave-washed slope of the moraine taken near the road over the hill].

Between Deer pond and Cannon Corners, from the north and south road going up the hill on the west to 800 feet in elevation; the slope is encumbered by a peculiar deposit which in many respects suggests strong water action as having shaped the gravels and cobblestones, but the unstratified masses higher up show that the ice sheet was concerned in the final distribution of the material.

The deposit lies immediately east of one of the large, barren rock tracts locally known as Blackman's rock, the interpretation of which is discussed below under the head of Spillways. The deposit probably marks the ice margin. Certainly, a little to the northwest in the valley of the English river and beyond the limits of the map, there is a well defined, low, bouldery moraine made by the ice sheet moving southwestwardly against the ground which here rises to the west. Stafford's rock, another spillway, extends northward from this deposit towards "the Gulf," a ravine near the boundary line, on the southern side of which heavy boulder deposits again appear.

In fact, the whole northern slope of the Adirondacks within the limits of this map and along the western bordering area is marked by deposits showing the retreat of the ice sheet. Almost everywhere from an elevation of 900 feet down to 700 feet there are marked signs of the interaction of powerful streams of water flowing along the ice margin, sweeping bare large tracts of rock and depositing bars and ridges of coarse cobbly drift, now in the open path of the torrent, now against the ice itself. The result is that the discrimination of rudely assorted, stream-transported blocks of the Potsdam sandstone from accumulations of similar material dumped at the ice margin or pressed by the ice into low ridges is often difficult and perhaps impossible.

Other small and apparently disconnected patches of frontal moraine habit appear at Wood Falls and in the low country north of Mooers Junction, between the elevations of 300 feet and



Topography by E. C. Barnard, U. S. G. S.
Surveyed 1893 in cooperation with the State of New York.

J B Woodworth 1903.

THE INGRAHAM ESKER

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

Contour Interval 20 feet
Datum is mean Sea level

320 feet. The latter deposit probably owes its distinctness to its being defended from strong wave action, which elsewhere to the southeast has locally greatly modified any such glacial deposits. About 2 miles east of Sciota on the northeast bank of Corbeau creek, there is a belt of morainal topography with deposits composed of stony till. It is probable that these deposits mark the position of the retreating ice front along a northwest and southeast line. I have drawn such a line on the accompanying sketch map [pl. 2].

Glacial drainage and spillways

Of the water action which went on, in and about the glacial sheet in this area, the usual results in the form of kames, eskers and sand plains are inconspicuous. One of the largest and finest eskers in the State, however, occurs on the area of the Rouse Point sheet immediately east, but no definite eskers have been seen on this area. This esker, which is traceable for about 10 miles as a more or less distinct ridge, is remarkable as showing how little modification of glacial form may be produced under favoring circumstances by submergence beneath the sea. The bearing of this esker on the late geologic history of the Mooers area is so close that the following notice of the deposit is here inserted.

Ingraham esker

This esker appears first to have been recognized by Dr Gilbert, who mentions it in his unpublished notes on this region. The village of Ingraham is strung along the eastern slope of the ridge and suggests the name here given. The accompanying map [pl. 4], with contours drawn by E. C. Barnard of the United States Geological Survey, gives a good idea of the course and position of the esker.

It is to be noted that its course is southerly in compliance with the direction of ice movement in this part of the Champlain valley. The short interruptions through which the several small streams pass are presumably original, low places in the ridge. Thus in the case of the Little Chazy river, it is not probable that the ridge at the point where it is crossed by that stream was originally much higher than it now is, else the stream would have

been diverted to the south along the course of Riley brook and so escaped to the sea or Lake Champlain. Such notches are normal features in many eskers where no streams occur. The marked crease on either side of the esker is quite characteristic and suggests that, as has been noted of some eskers in the upper Mississippi valley, the glacial stream occupied the bed of an older valley. The esker ends rather abruptly south of Ingraham and affords no evidence of having been the path of a stream connecting directly with a frontal outwash plain or esker fan.

I have examined the major portion of the length of the esker in the search for shore lines. Dr Gilbert first noted slight traces of a beach near Ingraham. Both the esker and the adjacent swampy depressions unfilled by marine or lake deposits show that this belt, which lies from 3 to 5 miles distant from the beaches at the base of the adjacent high ground on the west, received very little sediment during the sojourn of the sea over this field and thus is in sharp contrast with the deposits of marine sands and clays which occur along the lake shore. Below Ingraham the base of the esker is contoured by the 140 foot line; near its northern end by the 200 foot line. The ridge itself seldom if ever rises more than 40 feet above the adjacent low ground.

Deltas contemporaneous with ice fronts

Two classes of deltas of gravel and sand may arise along the margin of an ice sheet. First, those produced by the outwash of sediment from the ice by the discharge of its drainage; and, second, those deposits which are laid down by streams flowing toward the ice margin from the open country which it has perhaps just vacated. Deltas of this latter class may form terraces banked up against the ice margin, or, where temporary lakes form along that margin, the delta may take on its typical form and structure and not be distinguishable in itself from a delta built in any ordinary nonglacial body of water. All the principal streams in this area exhibit occasional deltas of gravel and sand, the upper ones of which are probably to be regarded as contemporaneous with the retreating ice sheet.

Alder Bend deposit

Along the banks of the Big Chazy river, from half a mile to a mile above Alder Bend, there is a deposit of gravel and sand mainly developed on the western bank of the stream. This appears to have been made in a temporary lake whose surface approximately coincided with the 1080 foot contour line, but no other evidence demanding such a lake for its explanation has been observed.

Deer brook deposit

On the north branch of the Big Chazy river northwest of Irona, there is a noticeable area of sands often fine, which is evidently the remains of a delta made on that stream. The deposit has suffered some dissection. The tops of the remnants lie between the 660 foot and 700 foot contour lines and indicate a local water level somewhere between these hights. No definite margin was detected in this deposit to indicate whether it was built up against the ice margin or under the free conditions of open water. The fineness of the sand toward the eastern extension of the deposit favors the latter supposition.

Altona deposit

A smaller delta than the preceding constitutes the flat ground on which a good part of the village of Altona is built. This deposit is decidedly gravelly south of the railroad. Just north of the railroad and west of the station, there is a deposit of fine sand, probably the lobate, free margin of the delta. All the circumstances here point to the building of the deposit in a body of water whose level corresponded with the 640 foot contour line, traces of which in the form of beaches occur to the east of Altona village. It is probable that the delta above described on the north branch of the Big Chazy was deposited earlier than this one in a higher water stage. The Altona delta appears to have been built by the Big Chazy before it had excavated its present course to the east of the village.

Deposits of gravel and sand in the form of deltas occur at lower levels, but they are so clearly associated with the marine invasion of the district that reference to them is deferred to a later page.

Spillways and the flat rocks

The most singular feature of the surface in the towns of Altona and Mooers is the occurrence of large tracts of the Potsdam sandstone, exceeding 12 square miles in area, barren of glacial drift. These bare areas are not entirely valueless, for the reason that in the proper seasons a large yield of huckleberries is obtained from these tracts. In the year 1902, $4000 worth of this fruit was sold by one concern alone from gatherings on the Flat Rock southeast of Altona.

The Altona Flat Rock is the largest of these barren tracts. Two very small and probably originally continuous bare areas known as Moose and Jericho rock occur at an elevation of about 1500 feet on the hillside southwest of Jericho. Southwest of Cannon Corners, extending on the unmapped area west of this sheet for the distance of about a mile and a half to the south, is Blackman's rock. Northwest of Cannon Corners and beyond the limits of the map is another tract known as Stafford's rock, north of which along the international boundary line is another area marginal to and extending west from "the Gulf," an abandoned river gorge and waterfall [*see* pl. 5].

Between Sciota and West Chazy, at elevations ranging from 260 feet to 500 feet above the sea, are small but noticeable areas of the Potsdam sandstone, from a quarter of a mile to half a mile across, bare of drift. The latter occur in the zone of wave action following the disappearance of the ice, the drift is not very thick about their margins, and their occurrence does not appear to demand a special explanation. It is different, however, with the larger areas lying above the 600 foot but mainly between the 700 foot and 900 foot contour lines; a system of bared rock surfaces which extends with slight interruption from the Canadian border on the north across the present lines of drainage around the northern slope of the Dannemora massif to the head waters of the Little Chazy river. With this system "the Gulf" on the boundary line near Covey hill is intimately connected.

To Dr Gilbert belongs the entire credit not only of looking for and finding these features, but also of having explained them.

The explanation depends on a simple consequence of the retreat of the ice sheet from high ground sloping toward its front. In the larger valleys blocked by the ice margin, contemporaneous glacial lakes will result. These lakes will have their outflow along the lowest point in their borders; thus the discharge may take place across the divide at the head of a valley, the usual condition; or it may take place along the ice front; or it may cut into a ridge which separates this valley from the next one. Where the land is relatively smooth, the drainage from the ice or that flowing toward the ice may be compelled to flow for miles along the front before discharging into the open country or a static body of water. All of these discharge ways along the ice front are denominated spillways by Dr Gilbert.

Jericho spillway

The first signs of a spillway in this district appear in Moose and Jericho rock, above mentioned, on the northern slope of Dannemora mountain at an elevation of about 1500 feet. When the ice sheet had disappeared from the crest of this massif, its front, probably extending northwest and southeast at right angles to the general line of motion, would have allowed the discharge of the waters confined along the northern slope of the mountain through the pass of Stillwater brook. The scouring of the rocks would thus be accomplished.

Great Flat Rock system

That the flat rock areas extending from Altona to "the Gulf" at Covey hill in Canada belong to a single great stage, is shown by their approximate agreement in range of altitude between 620 feet and 920 feet, their alinement along the same general slope, and by their approximate continuity.

Though the accompanying map shows considerable intervals of till-covered rock between the several bare rock tracts within the area, it is probable that a different mapping would somewhat extend the area assigned to the water-swept rocks. Between the Big Chazy south of Altona and the vicinity of Irona the original area of bared rock is undoubtedly much greater than is represented on the map. The district has been overgrown by forests and covered with vegetal debris. Here and there are certainly

clumps of till or rudely assorted, coarse debris. I suspect also that west of Irona, toward the western margin of the quadrangle, what I have mapped as ice-laid drift may in reality be in some part torrent-made debris; nevertheless, I was not able to come to such a decision regarding it at the time of going over it.

In the accompanying sketch map [pl. 5] I have attempted to show the fullest extension of the flat rock areas from Altona to those on the northwest.

Altona Flat Rock. This is the largest of these spillways in the district. It is at least 5 miles in length and varies from 1 to 2 miles in width. A number of its features are worthy of note.

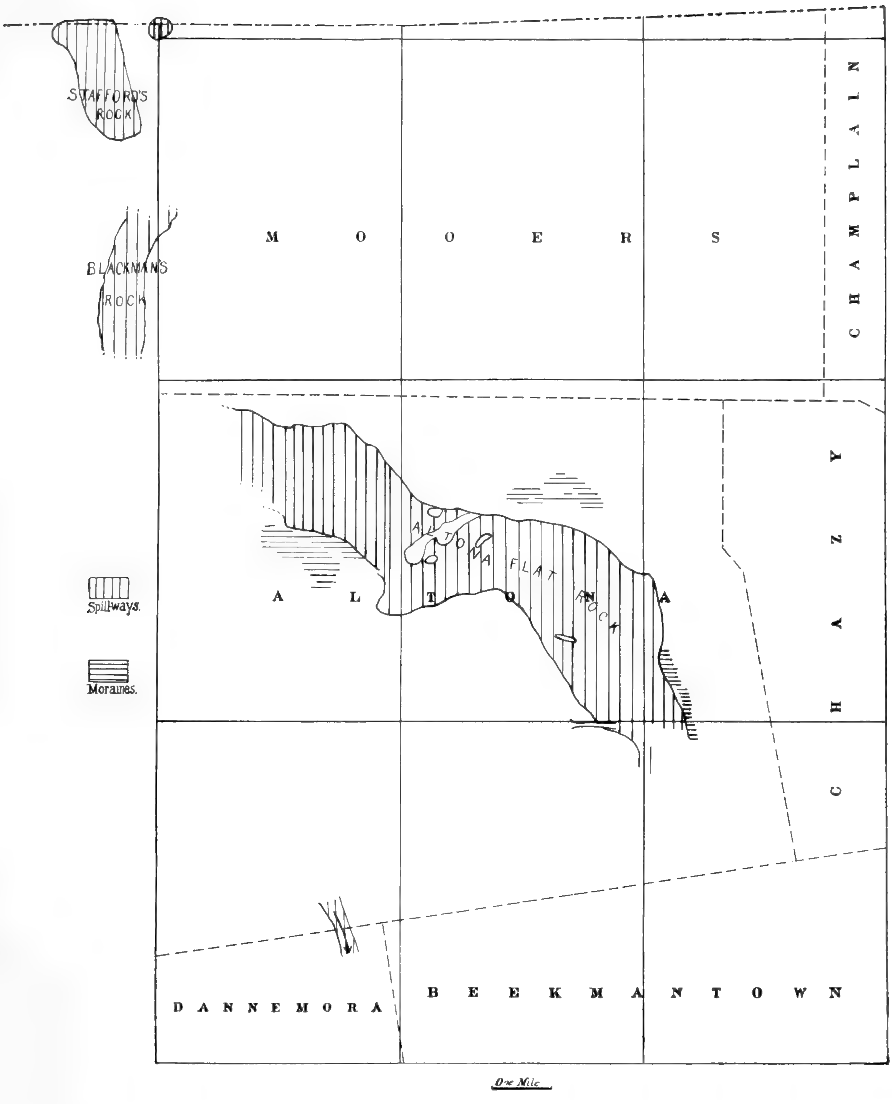
Cold brook, one of the head streams of the Little Chazy river, flows southeastward along the strike of the Potsdam (Saratogan) sandstone in a depression about 100 feet in depth.

The southern and higher margin of the stripped area is roughly determined by the 900 foot contour line. Its lower margin on the north and east is bounded by a beachlike deposit of waterworn cobbles at about 680 feet. For about a mile along this border the bare rock descends to a lower level (630 feet). On the southeastern extremity of this margin the bare ledges of "Pine ridge" are extended southward by a bouldery moraine which I have called Cobblestone hill. The wave-washed slopes of a portion of this moraine are evidently later than the moraine, which must have been constructed when the ice sheet lay against the northern and lower margin of the stripped belt.

The surface of the flat rock bears a few isolated patches of what appears to be till, remnants of the deposit which was laid on by the ice sheet during its occupation of the belt. Two of these patches of conspicuous extent are shown on the map. The boulders in these deposits are largely of the local rock, and many are well rounded, and it is possible that the deposits, as Dr Gilbert has suggested to me, are of torrent origin even where the rocks are decidedly angular. Loose, frost-riven blocks of the sandstone and the pebbles and sands derived from the secular weathering of the Potsdam are the sole surficial rock debris over most of the flat rock area [pl. 6].

There are several noticeable rock cuts which indicate the action of powerful streams capable of removing blocks of the

Plate 5



Sketch map of the Spillways, from the Canada line to the Little Chazy river, on and west of the Mooers quadrangle

Plate 6

View in the Altona " flat rock " spillway, about ¾-mile northwest of " Dead Sea ;" elevation 750 feet, looking s. 26° w.

Plate 7

The Dead Sea in the flat rock area southeast of Altona, showing a current-washed pool in the Potsdam sandstones; view from the head of the gorge. Looking east

Plate 8

The Dead Sea in October, 1902, looking s. 76° w.

Plate 9

View from western end of Dead Sea looking northeast to north wall, showing Potsdam sandstone and high water mark

Plate 10

View near Dead Sea, from east end of pool 100 feet east; looking north over the washed ledges of Potsdam sandstone, dipping away from observer

rock as fast as they were loosened. Such excavations as "Poxhouse gully," "Rattlesnake den," and "Leadmine gully" near Altona, if not existent previous to the time of the stripping, would seem to owe their origin to streams flowing down the natural slope of the rocks rather than to glacial torrents.

At the southeastern end of the area, about a mile northeast of Robinson, there is a deep trench not shown by the contours of the map. This trench extends partly through the till-covered rocks about the southern margin and in places is as much as 50 feet deep. At the time of my visit in 1902, there was a small stagnant lakelet held in by driftwood near the eastern part of the channel. Westward the channel passes into a partly drift-filled vale with kamelike habit, suggesting the presence of the ice sheet during the cutting of the gorge. It is probable that the channel is due to the escape of waters from the head of Robinson brook at a time when the ice front was passing away from the vicinity. That the channel represents glacial drainage rather than natural stream work is shown by the manner in which it cuts across the low spur of the sandstone shown by the northward loop in the 900 foot line on the map.

A more pronounced channel with a remarkable pool is found at Dead sea. This lakelet is apparently one of the group of abandoned waterfall pools, for the reason that no permanent stream capable of making so large an excavation now traverses the area [pl. 7-10]. The waters which produced the Dead sea rock basin evidently flowed eastward; the same is true of those which produced the channel near Robinson. All the ascertained phenomena from this district bearing on direction of water movement show that it ran eastward across the col at "the Gulf" south of Covey hill; southward along Stafford's and Blackman's rocks; thence southeastward past Irona and over the Altona Flat Rock district.

In the case of the Altona Flat Rock tract, it is to be noted that bared ledges begin on the west at a point where the retreating front of the ice sheet might have diverted the Big Chazy river to the eastward along the ice margin; and, whether or no waters came along from the west, including those of the north branch

of this river, some scouring of the drift would thus have been accomplished.

The mere breadth of the Flat Rock area might be explained by the gradual stripping of the drift along the receding ice front, without making it necessary to suppose that this belt was at any one time entirely covered by a torrent. The bare surface of Pine ridge, north of the deep vale of Cold brook, however, makes it difficult to see how a stream of small width as compared with the breadth of the stripped belt could have followed the retreating ice front to the north of this depression. A broad and powerful torrent of waters comparable to that which must be evoked for the work done at "the Gulf" could reasonably be supposed to have filled this depression and scoured the rocks on either side. While some of the phenomena are explicable on the hypothesis of a continual shifting of a small stream, there are still other considerations which appear to demand a broad and powerful torrent flowing over the district. Thus, in the case of the Dead Sea basin, its reported depth of from 42 to 90 feet appears to be greater than can be expected for the work of so slight a fall as the rock cliff [*see* pl. 8] at its head would indicate if the stream were a small one; but it is quite conceivable that a heavy torrent might have produced the results.

The location and vertical distribution of beaches about the southeastern end of the Flat Rock area and for a considerable distance along its northern margin show that the torrential waters which produced this field of bare ledges discharged into a standing body of water along the course of the Little Chazy from 3 to 4 miles west of West Chazy at an elevation at least 600 feet above the present sea level. The disposition of the cobbles, gravel, sand and clay which must have resulted from the stripping of such large tracts of drift is not altogether satisfactorily accounted for. It will be noted on the map [pl. 26] that the marine-modified drift south and west of West Chazy must be relatively thicker than is this group of material north of that village, for there are no outcrops of the bed rock observed in this survey in this southern belt between the 300 foot and the 700 foot lines. Heavy bars and ridges of waterworn drift there occur, and the unusually thick deposits are probably to be attributed primarily to the wash from the flat rock districts.

A full and satisfactory account of this series of spillways can hardly be presented till the region on the west of the Mooers quadrangle has been mapped. The outlines of these bare areas shown on the sketch map [pl. 5] are mere approximations obtained from a single traverse of the area between the north branch of the Big Chazy and "the Gulf."

Blackman's rock. Half a mile southwest from Cannon Corners there begins a bared strip of the Potsdam sandstone which stretches southward nearly to the north branch of the Big Chazy river. Only the northeasternmost extension of this spillway appears on the Mooers quadrangle. This spillway stands at an elevation of about 800 feet.

Stafford's rock. This stripped area lies wholly west of the Mooers quadrangle and extends from near the north bank of the English river toward "the Gulf" on the south side of Covey hill. It is reached by taking the first left-hand road north of Cannon Corners, which may be followed out northward to "the Gulf." The area appears to be separated from the flat rock at "the Gulf" on the international boundary by a torrent-washed or at least a bouldery moraine.

Armstrong's bush flat rock. The settlement in the wooded district of the northwestern corner of the Mooers quadrangle is known as Armstrong's bush. In the extreme northwest corner of the quadrangle and extending across the boundary line into Canada is a small stripped area lying between 750 feet and 770 feet elevation and at the top of a low hill. Its relation to the other spillways is not perfectly clear.

From the distribution of the frontal moraines and these spillways, it would appear that for some time before the ice sheet melted away from the north slope of Covey hill, its edge as an unbroken wall extended along the northeastern face of the Adirondacks between the 680 foot and 900 foot contour lines from Covey hill southeastward to the Little Chazy river in the vicinity of West Chazy. At this last named locality, at least in the later stages of the torrential action along its border, the ice front turned eastward across the valley of Lake Champlain but without leaving, so far as is at present known, any definite frontal deposits. In front of the ice over the southern part of the

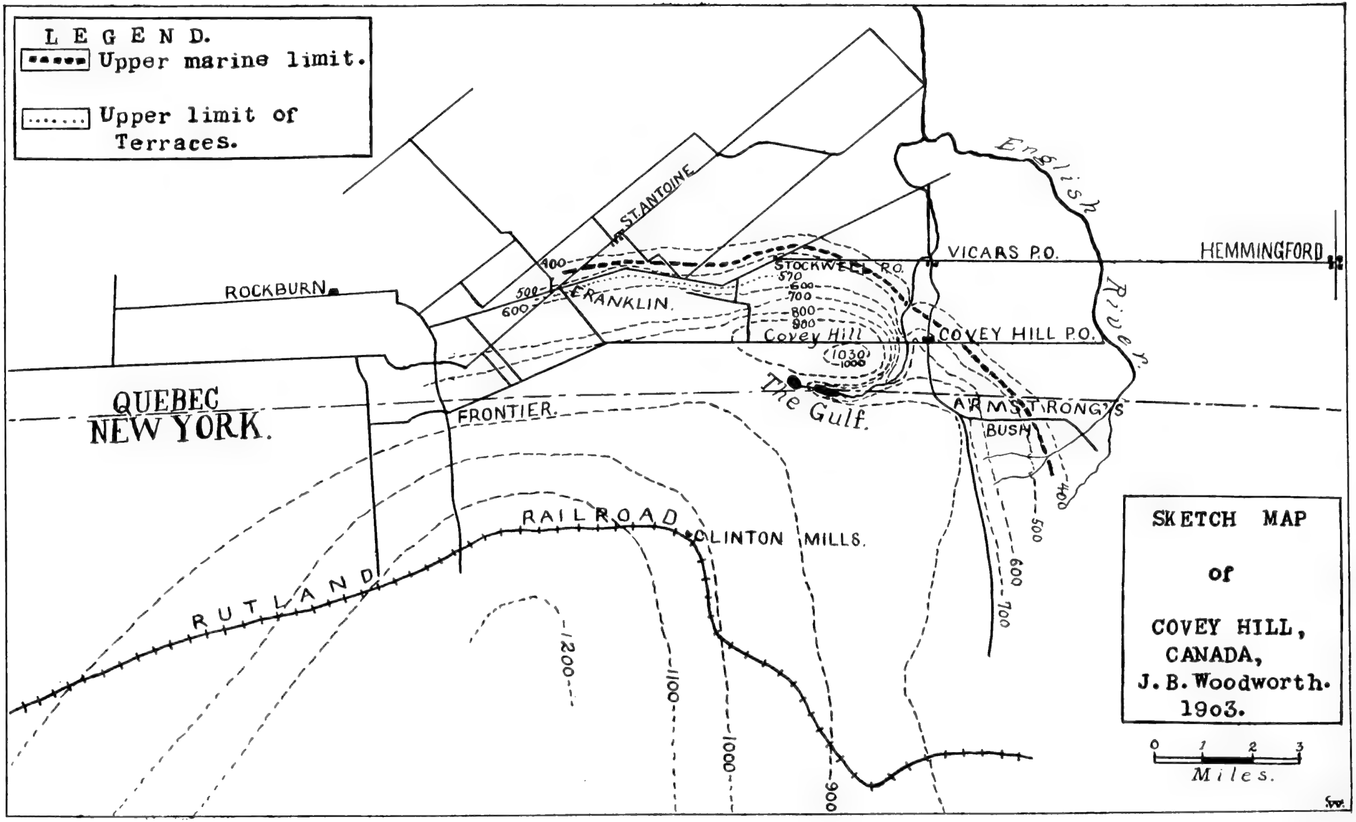
Champlain valley stood a fresh-water lake held in on the north by the ice front.

With the retreat of the ice from the northern slope of Covey hill, the waters heretofore pouring along that front on the west of the hill and forced over the col into "the Gulf," began to escape around the northern slope, thus leaving "the Gulf" and its waterfall without an apparent cause for existence. The pool at the base of the fall remains as a lakelet fed by springs, an "abandoned Niagara."

"The Gulf" at Covey hill. Mention must be made in this account of the most interesting feature connected with these spillways in the remarkable ravine known as "the Gulf," which lies just beyond the northwest corner of the Mooers quadrangle and partly across the international boundary. Its importance depends on the light it throws on some of the problems which arise from the occurrence of shore lines and spillways within the limits of the Mooers quadrangle. The general topographic features of the vicinity of "the Gulf" are shown on the accompanying sketch map [pl. 11].

"The Gulf" is quite as remarkable as the chasm of the Ausable. It appears to have been visited by Ebenezer Emmons, the geologist in charge of the second district, and is briefly described by him in his report on Clinton county in 1842 as being "300 feet deep and about 16 rods wide." He mentions the statement that the small lake at the bottom is 150 feet deep, the accuracy of which may still be doubted. "At the present time," he states, "no causes are in operation sufficiently powerful to remove the broken masses from a gorge of this description. . . At this place there is merely a small rill discharging itself from a small lake of dead water, insufficient in itself to accomplish any perceptible change. To account for the present condition of this rock, we have therefore to go back to a period, when some current swept through this gorge with great force and power; for by no other means could the materials, which once filled the space between the present walls of the gulf, be removed."[1]

[1] Emmons, Ebenezer. Geol. N. Y. 2d Dist. 1842. p.309–10. *See also* by same author, Agric. N. Y. 1846. 1:133–34.


LEGEND.
Upper marine limit.
Upper limit of Terraces.
SKETCH MAP of COVEY HILL, CANADA, J. B. Woodworth. 1903.
0 1 2 3 Miles.
QUEBEC
NEW YORK.
FRONTIER.
ROCKBURN
ST. ANTOINE
FRANKLIN.
STOCKWELL R.O.
VICARS P.O.
HEMMINGFORD
COVEY HILL P.O.
Covey Hill
(1030)
The Gulf.
ARMSTRONG'S
BUSH
English River.
CLINTON MILLS.
RUTLAND RAILROAD
400
500
570
600
700
800
900
1000
1100
1200

This quotation is given here for the reason that it appears to be the first recognition of an important class of abandoned gorges found in New York State excavated across northward extending promontories of rock and lying so far above the present drainage of the country that no existing stream under the geographic conditions of the day could have performed the work. Dr Gilbert appears to have been the next geologist to examine this gulf and the first to understand it: it was he who first called my attention to its existence. His notes on the place give the depth of the ravine as 160 feet; top of cliff above lower lake, 805 feet above sea level; the lower lake, 645 feet above sea level; upper lake, 830 feet above sea level; bluff above upper lake, 870 feet above sea level; swamp at summit, 875 feet above sea level; margin of channel opposite swamp on north side, 900 feet; water level of torrent at swamp inferred to have been between 900 and 910 feet. These are aneroid readings compared with the U. S. G. S. measurement of the elevation of Covey hill top, which is given as 1030 feet. No accurate measurements have yet been made of the depth of the upper and lower lakelets. The international boundary line crosses the lower lakelet as shown in plate 11. The upper lakelet lies wholly within Canada.[1]

The small lakelet at the foot of the cliff at the head of the gorge is clearly a waterfall pool, analogous to Green lake near Syracuse. The lower lakelet at the eastern end of the gorge, where the valley widens out into a depression of more ancient date, appears to be due to the choking of the valley at the eastern end of the lakelet as if a powerful stream reaching this point was checked and forced to drop its load. At the lower margin of the upper lakelet there is a heap of angular blocks of the Potsdam sandstone showing the action of the turbulent currents once active within the pool.

The rock on either side of the brink of the gorge and particularly along the southern side is stripped bare of drift and displays

[1] "The Gulf" is most easily reached from the south by driving from Mooers to Armstrong's Bush in the northwest corner of the quadrangle, thence to Covey Hill postoffice and westward over the top of the hill to Mr Donnelly's or farther on to Mr Sutten's place, from the latter of which a private road leads to the head of the gorge and the bare rock of the channel above the abandoned waterfall.

all the characters of the so called Flat rock or spillway so well shown about Altona. On the west the old stream bed springs as out of the air across the swamp near the crest of the col. Nothing else than the front of the Wisconsin ice sheet, pressed against and around the northern slope of Covey hill and the northern flanks of the Adirondacks to the westward, could have held up to this elevation the waters which discharged eastward through "the Gulf" to the lower levels of the Champlain valley. The present investigation has not determined the precise origin of these waters—whether they came from the ice itself, from the large streams which, descending the northern slopes of the Adirondacks, discharged against the ice front; or whether any part of the water passed along the front of the ice to this point from the northeastern extension of some stage of Lake Iroquois, a large fresh-water lake retained over the site of present Lake Ontario by the western extension of the same ice dam which is here invoked for the anomalous drainage feature of "the Gulf."

The facts at "the Gulf" warrant the conclusion that, at the time the ice sheet stood along the boundary so as to hold the drainage up to this col, there was a free run off for the water from at least the upper lakelet at an elevation as great as 830 feet above the present sea level. This, as will be shown later, precludes the idea of a glacial lake existing above this level at this particular time over the Champlain valley. The same remark holds true for the bottom of the gorge at the lower lakelet: while the water still flowed through this gorge at the latest stage a glacial lake could hardly have existed to the south and east at a higher level than the 645 foot level. [*See* p. 41 for further bearing of facts at Covey hill on water levels]

"The Gulf" is a witness also against the presence of the sea within the range of its elevation and shows that the deltas and shore lines within these levels southward along the slopes of the Adirondacks are not of marine origin.

Small rock exposures

The small rock exposures shown on the map—care has been taken to show all that were observed—fall into two groups, artificial and natural exposures. The artificial exposures are in this

district almost entirely in road and railway cuttings, but many along these lines of travel are also natural exposures, particularly in the zone of wave action.

The natural exposures are mainly due to the sweeping away of the drift and beach materials along the beds and banks of streams, and in the low grounds from elevations of 600 feet downward, to the scouring action of waves. Their distribution serves to show that over most of the area the covering of glacial deposits and the wave-modified drift derived from them are on the whole thin. Where these small exposures are crowded, the surficial deposits are thinner than in regions where the outcrops are widely scattered.

LATE AND POST-WISCONSIN LAKE AND MARINE DEPOSITS

The complicated course of events attending the disappearance of the ice sheet from the northern slope of the Adirondacks can perhaps be understood if it is remembered that, while the torrents which produced the spillways were discharging along the ice front over the district from the south side of Covey hill to the Little Chazy, the ice sheet was gradually receding from this position, that over the site of Lake Champlain a glacial lake was expanding northward foot by foot with the recession of the ice front, and that standing water crept in between the ice front and the eastern margin of the flat rock areas. As the ice still further withdrew, an open lake existed for a time with an ice barrier for its northern shore, stretching in an ill defined line from Covey hill to the northern versant of the Green mountains. It was still the Wisconsin glacial epoch. The ice next disappeared from the entrance to Lake Champlain, and the sea came in and began a new series of processes. The Wisconsin epoch locally had closed, and a new epoch with essentially nonglacial processes of change had been introduced. This epoch is the only true "Champlain" epoch of the Pleistocene period. The sea did not apparently stand as high against the land as did the earlier lake shores. The beaches of both series are preserved on the Mooers quadrangle, and it is difficult to distinguish between them as one traverses the wave-modified belt from the lowlands near Lake Champlain to the upper limit of

beach ridges at the eastern margin of the bared rock areas denominated spillways.

In the low grounds there are other deposits—beds of gravel, sand, and clay sometimes in the form of deltas, often occurring as flats. Marine fossils occur well up toward 350 feet in the area from Plattsburg northward and shells afford decisive evidence of marine submergence up to 340 feet near Mooers.

In general, the glacial deposits which have been worked over by waves occur in three fairly well defined belts or zones, viz:

1 A cobbly beach zone, several miles in width and ranging from an elevation of over 700 feet on the north to 640 feet on the south and thence down to about 250 feet.

2 A sandy zone looping up into the area of the first zone but lying mainly lower and somewhat farther east; and often characterized by glacial erratics of small size not definitely arranged by wave action.

3 Nearer the shore of Lake Champlain a clay zone more or less overlapped by the eastward extension of the sand zone. This clay zone lies almost altogether to the east of the Mooers quadrangle, but ramifications of it extend up the valleys of the rivers as high as the 250 foot level as near Mooers.

Shore lines of the area

The area covered by this atlas sheet displays the greatest array of abandoned and elevated beaches to be seen anywhere on the New York side of the Champlain valley. In the vicinity of West Chazy, unquestionable wave action can be traced up to an elevation of 675 feet above the present sea level. Along the international boundary unquestionable wave action can be traced within the limits of the map, from 280 feet up to about 540 feet. Above this hight in the northwest corner of the area in the district known as Armstrong's Bush, probable wave action appears at 620 feet to 630 feet, and again at 720 feet above the present sea level.

The accompanying map [pl. 26] shows the beach ridges where they have been seen. Except near the larger streams, where sandy deltas are developed, the slopes between the 450 foot contour and the 360 foot line are thickly beset with wave marks. The beach

lines, in the form of low ridges, often crowded closely together, are particularly numerous northwest of the English river along the international boundary between 360 feet and 500 feet. I counted 25 such ridges between the 365 foot and the 450 foot contour lines. From Bullis brook south of Mooers to the southern limits of the sheet, the surface is ribbed with beaches almost everywhere apparent, from 500 feet down to 320. Higher wave marks also occur in this part of the sheet. Lower wave marks are seen on the Rouse Point quadrangle to the east.

The location of the numerous beaches shown on the map and their position with reference to the contour lines were determined by eye estimates in traversing the areas where they occur. Any single beach ridge can seldom be traced satisfactorily for any distance; it may fade away, merge into other lines, or become lost in second growth timber, where its slight relief, added to the other difficulties named, would make the detailed mapping of the many similar beaches on this area hardly worth the expenditure of time and money. I have reason to believe that many of the short beach lines shown on the map are really more extended. Careful leveling would also, I believe, show a greater divergence between the beach lines and the contour lines. It is to be presumed that the contour lines are correctly drawn. It is noticeable however that they are drawn to follow the prominent beach lines; but the evident decline of the principal wave zone from north to south appears to indicate very clearly that the beach lines are not level lines, yet no beach as before noted proved sufficiently distinct and continuous to make the test of walking one out across the area available for determining the degree of tilting.

The principal object of the study and mapping of the beaches has been to determine if possible the upper marine limit in this field, and the question at once arose whether all the beaches were marine or whether some of the higher ones were formed in a fresh-water lake in front of the retreating ice sheet. It has been seen how "the Gulf" would place the marine limit below 645 feet of elevation.

The lower beaches up to at least 340 feet above the present sea level are shown to have been made by the sea by the existence of marine shells in the contemporaneous deposits. There appear to

be no characteristics by which marine beaches as such can be discriminated from lake beaches. As will be shown in more detail in a report now in preparation on the whole question of the marine invasion in the Champlain and Hudson valleys, certain reasonable assumptions may be made with regard to the distribution of beaches, by means of which, when the expectations are met, the marine beaches in this area above the fossil shells and below the level of the Gulf may be distinguished from those made in glacial dammed lakes. In the first place, elevated marine beaches may be expected to be traceable with more or less continuity throughout the entire borders of low ground to which the sea must have had access; the beaches may be expected to succeed each other at any given place without very noticeable breaks in the vertical succession, as a consequence of the rather uniform nature of the elevation of the land above the sea. Glacial lake beaches, on the contrary, would be expected to end where they met the ice front, they should not therefore be continuous where sea beaches would be continuous; the sudden lowering of a glacial lake by the uncovering of a new outlet would cause noticeable intervals in the vertical succession of these beaches; and particularly might an interval be expected between the lowest lake beach level and the upper marine limit.

There are other minor differences with regard to the development of lake and marine beaches which may be expected in the Champlain district. In the making of marine beaches, the strength of the wave action at any place depends in part on its exposure, and that on the fetch of the winds across the water body. Where the topography and materials to be wrought by the waves are essentially the same from higher to lower levels in a given portion of the area traversed by the regression of the sea, a like strength of beaches is to be expected.

In the case of deep waters along an ice front, the heaviest wave action may be expected to occur independently of the conditions which control normal marine waves. It will take place at or near the junction of the shore line with the ice front; for there the calving of the ice front in the production of icebergs will set up heavy waves, the force and direction of whose action will be independent of the prevalent winds and the more remote

geographic conditions of the lake or fiord seemingly protected coasts are thus rapidly waveworn, an observation which Dr Gilbert personally communicated to me from his experience in Alaska. In a glacial lake such wave-made beaches would frequently occur as worked over morainal deposits recently abandoned by the retreat of the ice sheet. Such wave action would cast up materials higher than waves would reach along the shores removed from the ice front.

The magnitude and power of berg-made waves in situations where wind-made waves can hardly reach any considerable size, has been vividly described by Dr Isaac L. Hayes[1] from personal experience in the Sermitsialik fiord on the west coast of Greenland in the voyage of the steamer *Panther*. The calving of the front of the glacier which enters the sea in this fiord produced a wave of vast proportions. "The wave," states Hayes, "occasioned by an earthquake only can be compared with it in magnitude and force. . . Waves of considerable though not dangerous magnitude followed, and it was quite half an hour before the waters were at rest."

Upper limit of beaches

The upper limit of beaches or to be more concise the upper limit of wave action on the Mooers quadrangle appears to be found in the northwest corner of the area at 720 feet according to the local contour of the map, but west of the area mapped a possible higher deposit occurs at the corner of the road to Covey Hill postoffice. This 720 foot deposit is a coarse cobblestone bar ending on the south with a spitlike hook just north of Kellas brook. Beachlike ridges also occur to the south along the road at 720 and 725 feet, and again at Cannon Corners on either side of the English river as shown on the map. Possible wave marks occur on the south of the English river as high as 750 feet according to the contours of the map. Still farther south along the western border of the quadrangle and north of Deer pond, what appears to be weak wave action is indicated by the configuration of the ground and rounded gravel at about 705 feet. On the hillside west of this locality water-

[1]Hayes, Isaac L. A Visit to a Greenland Glacier. Harper's New Monthly Magazine. January 1872. 44:212-13.

worn cobbles form a steep slope nearly to the 800 foot contour line but I have not been able to distinguish this deposit from waterworn material deposited in the presence of the glacier and worked over by it. It is not discriminated from the general local drift coating on the accompanying map.

South of Deer pond and thence southeastward along the curving contour of the flanks of the Adirondacks I have not been able to find traces of wave action above 680 feet along the northern margin of the Altona flat rock or spillway, above 670 to 675 feet in the region west of West Chazy, and above 640 feet at the southern limit of the map.

Water may have stood at a higher level with waves beating against the flat rocks but these bared surfaces would have yielded little material for making recognizable beaches. The 680 foot level is very indistinct or locally wanting along the eastern margin of the Altona flat rock area in the southern part of Pine ridge where the stripped rocks descend to lower levels than usual. The absence of definite beaches therefore between Deer pond and Altona does not necessarily mean the absence of wave action within the zone at which it might be expected if it is granted that these supposed wave-made deposits marked a former water level now tilted to the southward.

The falling off in level of this tracing of highest beaches is as much as 110 feet at least between Cannon Corners and the southern margin of the quadrangle. In an air line in a northwest and southeast direction this amounts to a rise on the north at the rate of about 6.5 feet to the mile, or if we neglect any possible eastwest tilting, and compare the two localities in a north and south direction, the rate of tilting is about $7\frac{1}{3}$ feet to the mile.

The rather persistent beach at the 680 foot contour on the north side of the Altona flat rock extending in an east by south direction for about 3 miles lies at a very large angle to the evident direction of tilting and this fact will account for the approximate uniformity of level which the water lines there show.

These estimates of the degree of tilting involve the supposition that the highest lines are parts of one water level. There are good reasons for thinking this not the case. It is evident that

they are the traces of successive stages of water action along the border of the ice. In a later part of this report the attempt is made to correlate them with different levels of a glacial lake which has left more definite traces over the southern border of the quadrangle, but whose tilting does not exceed 4.5 feet to the mile to the south. In fact there is no very definite upper limit to the signs of water action in this field and certainly none that can be traced continuously across the area. Far above this field to the west as the ice withdrew from the district, streams of water coursed along the ice border, building stream bars and plains of gravel and sand wherever space was provided for temporary lakes; gradually as the form of the ground favored the process larger lakes ending in one large lake came into existence and this extended northward over the Champlain valley as the ice front retreated. With regard to the beaches and signs of wave action in the quadrangle, the following account groups them roughly in two series.

Upper series of beaches

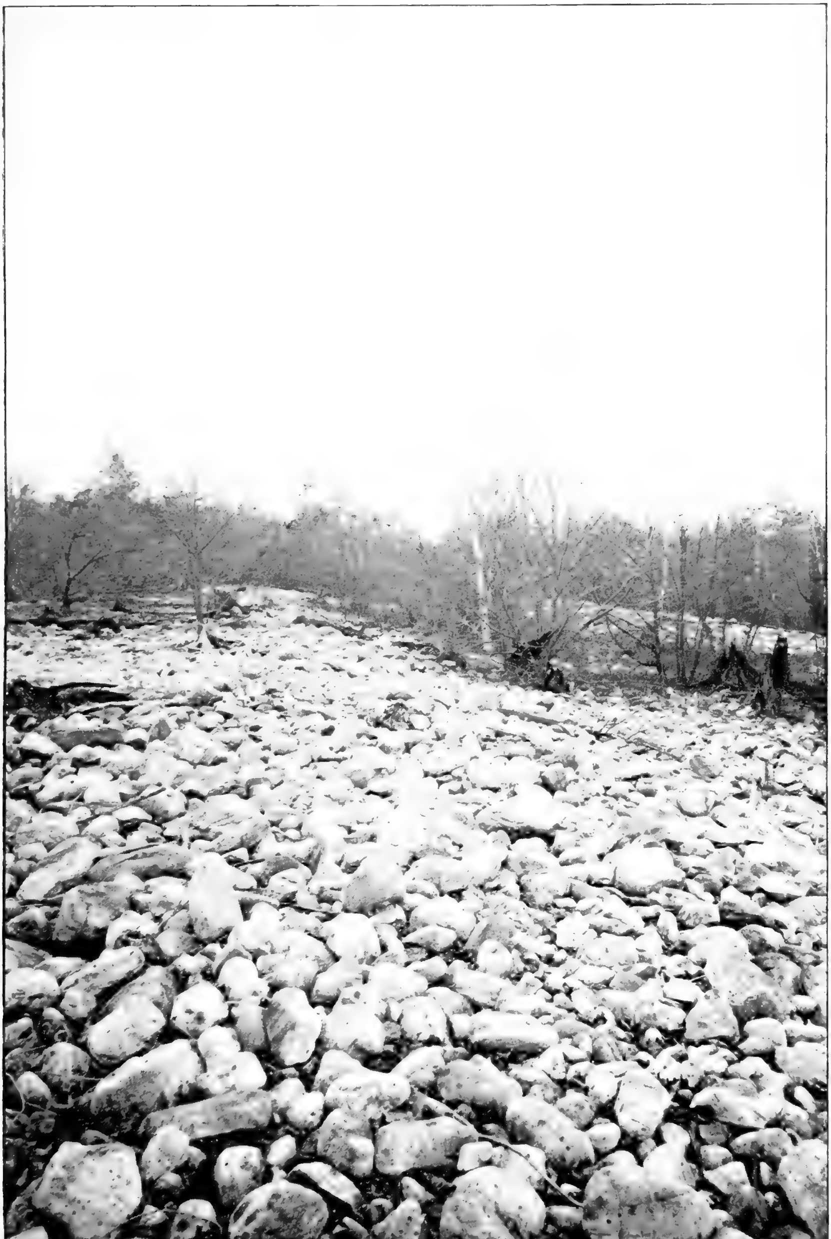
The upper series of beaches on the Mooers quadrangle comprise those higher water level traces of the area of which no satisfactory evidence has been found extending beyond the limits of the map around the northern slope of Covey hill on the Canadian side of the boundary line. These water levels are believed to be mainly the margins of successive lower and lower stages of a glacial lake which gradually extended northward in the Champlain valley with the northward recession of the Wisconsin ice sheet. The evidence on which the upper beaches are distinguished from a lower group of marine origin is such as to make what is apparently an arbitrary division of the beaches in this particular area.

Along the northern edge of the quadrangle at the international boundary, the upper series as here defined includes those traces of water action which appear above 450 feet. It will be noted by an inspection of the map [pl. 26] on the rather steep slope between the 380 and the 520 foot levels, averaging about 140 feet to the mile, the beach ridges are well developed and closely crowded. Above 538 feet no traces of beaches in the northern part of the map are shown till the 620 foot level is reached, where scanty evidences of possible beach action have been seen at one place in

the northwest corner. A second higher interval without definite traces appears between 620 and 720 feet at the upper of which elevations a beachlike ridge of cobblestones terminating southward in a recurved spit or hook is found at the head of Kellas brook. Southward from this point isolated traces appear at mainly higher levels up to 750 feet south of the English river which are tentatively regarded as the work of waves rather than of running water. About half a mile west of the Mooers quadrangle, where the road south of the boundary line turns northward toward Covey Hill postoffice, at an elevation by the aneroid of about 820 feet, there is a repetition of the cobblestone deposits at the 720 foot level. These upper deposits at 620, 720 and 820 feet along the international boundary are not certainly beaches; they may be the products of streams of water coursing along the ice margin where it met the confronting slope of the land at these respective levels. The association with the spillways suggests this relation. Nevertheless if they are not true water levels they appear to fall in certain planes of tilted water levels shown farther south.

In the southern part of the area in the latitude of West Chazy beach phenomena are nearly continuous from about 675 feet down to the eastern limit of the area. Beginning at the top, the most conspicuous example is found at the locality which I have named Cobblestone hill.

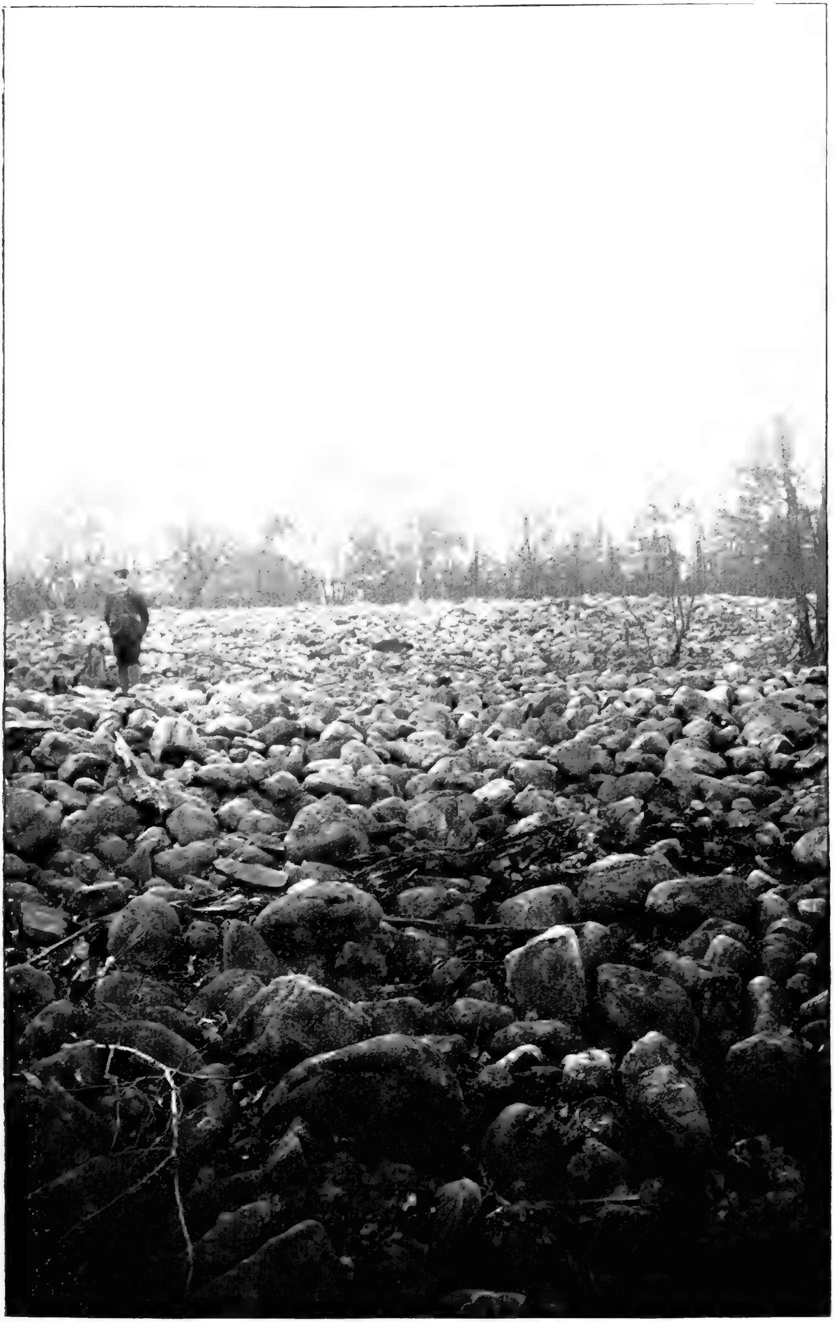
Cobblestone hill beaches. The highest distinct wave marks in the southern half of the Mooers quadrangle lie, as nearly as I have been able to determine by the aneroid and a comparison of the contoured map with the ground, between the 640 foot line on the extreme south and the 680 foot contour line near Altona. This line of wave action can be traced with some breaks from a point on the northern margin of the Flat Rocks 1 mile southeast of Altona along the margin of the Flat rock area to the series of beaches which form the eastern face of the high morainal wall stretching off to the south from Pine ridge and terminating at the Little Chazy river. South of the Little Chazy, the beach ridge reappears on an elongated hill at an elevation according to the local contour, of 675 feet, and reappears farther south between the upper branches of Ferrel brook at about the



View looking north along the eastern slope of Cobblestone hill, just below the crest

Plate 13

View looking north along Cobblestone hill, a lower beach than that in plate 12



The crest of Cobblestone hill, showing strong wave action on boulders and large cobbles. Looking west. Elevation 650 feet

same level. I was not able to recognize any distinct beach at or near this level farther south on this area.

At the point of beginning near Altona the beach is distinctly ribbed and contains many angular blocks along with water-worn cobblestones. The deposit is raised some 3 or 4 feet above the surface of the bare flat rock whose surface, following the local dip, shelves steeply beneath the beach.

At Bert Waitman's berry camp, a locality 1.1 miles distant in a n.n.e. direction from Dead Sea, the bare rock extends a few rods below and north of a line of subangular boulders, whose elevation according to the aneroid measurement is 680 feet, a deposit which taken by itself is not suggestive of a beach. Glacial striae were observed here on the rocks (n. 31°e.).

At a berry camp on the margin of the rock, reached by a road going southwestward from Sciota, no trace of wave-strewn cobbles or blocks was observed at 680 feet, and, as noted above, the bare rock descends nearly to the 620 foot contour line. It is conceivable that along this part of the line the wave action was such as to remove rather than deposit longshore drift.

South of the locality last mentioned, the partly wooded surface of the stripped rock shows here and there a block or group of blocks of sandstone in positions suggesting wave action. No trace of a water level at or near the 680 foot line was detected on the northern part of the morainal spur composed of very large sandstone blocks, which joins the southeastern point of Pine ridge. Wave action appears however at a somewhat lower level, in the most pronounced manner on the extension of this morainal ridge, which forms a detached mass somewhat to the south and east, named, as before noted, Cobblestone hill on the map which accompanies this report [pl. 12-14].

Apparently this hill was originally a morainal wall laid down along the ice margin at the southeastern extremity of the Altona flat rock area. It is one of a series of elongated drift ridges which extend *en échelon* from the southern end of Pine ridge along the eastern base of Rand hill in Beekmantown approximately between the 600 foot and 700 foot contour lines. Its form on the atlas sheet is imperfectly shown. The northwestern part rises above what is here termed the crest of wave-heaped cobbles.

The hill is composed altogether of blocks and cobbles of the Potsdam sandstone. On the wave-heaped crest and the western landward slope the blocks are still prevailingly angular, and there are no signs of strong water action other than the bare flat rocks. But from the crest down the eastern wave-washed slope the blocks are often well rounded, and are particularly so at lower levels. The fragments decrease in size from the crest, and near the 600 foot level are coarse gravels. The larger blocks are between 3 and 4 feet in length, but blocks yet larger occur. Ovoid masses of this size in the upper zones of beach action attest the strength of the waves which reshaped this side of the hill.

The eastern slope exhibits a number of benches of these boulderets and cobbles arranged in the manner peculiar to regressive wave action. The crest, tolerably uniform in elevation, is a narrow ridge, about the northern and southern ends of which the cobbles of the shelf next below are extended in well formed recurved hooks.

The third level below the crest extends northward along the slope of the ridge, which is there lower and, like the continuation of the beach on the second level, loses its beach aspect near the northern end of the hill.

I was not able to identify any signs of this wave action at similar levels on the equally strong morainal ridge just north and west of the hill.

The southern end of Cobblestone hill falls off to a lower level with signs of wave action along the crest of this extension, and about halfway down its eastern slope. Below 600 feet the surface of the main ridge is heavily covered with coarse gravelly deposits forming an even slope characteristic of the zone just below strong wave action.

In a subsequent report it is planned to give a sketch map and more detailed account of this deposit.

Neither north nor south of Cobblestone hill, within the zone of abandoned beaches to which this group of strand lines belongs, are there indications of such strong and long continued wave action. The extreme localization of the effects has seemed to me possibly explicable on the view advanced on a previous page, viz, that the ice front for some time stood near this hill on the north,

and that the waves set up by bergs forming along the ice front were the cause of the phenomena. With the surface of static water as high as the 640 foot contour line at this locality, there would have been a depth of water of 140 feet at a distance of 1 mile, of 240 feet at a distance of 2 miles, 340 feet at 3 miles, depths far less than those in Greenland fiords, but not as I conceive it, incompatible with the idea of berg-made waves of a magnitude greater than wind-made waves in an open body of water in the same position.

Against the view of berg-made waves, it is to be noted that Cobblestone hill stands out in a more exposed position than the similar ridges immediately north and south of it; and that the benches of cobblestones on its wave-washed face range through over 30 feet of elevation, as if the cause persisted through a change of water level.

The highest beaches detected south of Cobblestone hill appear to be along the same water level, falling off gradually in elevation as the shore line is traced southward. The elongate hill which rises to the 700 foot contour line between the Little Chazy river and the north branch of Ferrel brook is decidedly ribbed on its eastern face at about 670 feet. In the flat at the eastern base of the hill, in the woods, at 630 feet (aneroid) there is a stony belt suggesting brief wave action.

Still farther south, between the branches of Ferrel brook from about 670 feet down to 625 feet (by contours of the map) there are four wave marks, the uppermost of which is traceable for about $\frac{3}{4}$ of a mile.

Between the southern branch of Ferrel brook and the northernmost branch of Silver creek, faint wave marks are distinguishable from 650 feet down to 590 feet.

Southward of these indications to the southern limit of the map (44°45′n.lat.) the steep slope of the base of Rand hill, between 600 feet and 630 feet at least, is smoothened with rubble which appears to have been deposited under water or under the action of light waves as the water surface passed from higher to lower levels of the hillside.

At the extreme southern limit of the sheet and south of the road to Dannemora, a strong ridge appears delimited on the atlas

sheet by the 640 foot contour line. The loose rubble which mantles its surface, particularly on the east, is strongly suggestive of wave action. From this locality westward up the slope of Rand hill the surface is till-covered, becoming morainic in character, with kettle holes indicating the deposition of much glacial drift in the presence of melting ice.

Throughout the entire length of the Mooers district but few positive traces of wave action occur between the 500 and 600 foot contour lines. Along the road parallel with the international boundary, in the district locally known as Armstrong's bush, there are no marks between 540 and 620 which can be attributed to wave action, nor are any phenomena of the sort observed except for the slight indications below noted till one passes south of Bovington brook near West Chazy. The possible exceptions are the weak signs of wave action north of the English river between 510 feet and 515 feet, the weak beaches on the hill midway between Sciota and West Chazy at elevations of 540, 550, and a possible case at 590 feet. This ridging of the drift at 590 feet occurs also about a mile and a half west near the margin of the Altona Flat Rock area, with a 600 foot ridge immediately west of it.

On the road from West Chazy to Cobblestone hill, possible wave marks occur at 540 feet, 545 feet, and again on the eastern and northern slopes of the low hill marked by the 580 foot line. Along the eastern base of Cobblestone hill and northward toward the edge of the Flat rock area, there are beach levels continuous in series with the Cobblestone hill group from 610 feet down to at least 590 feet.

South of the Little Chazy river, there is an apparent beach north of the main branch of Ferrel brook at about 530 feet (from the map). Another narrow beach ridge with a hook at its northern end occurs along the road going south from West Beekmantown at about 550 feet according to the local contour; and southwest of this town the 500 foot contour line apparently follows the crest of an offshore bar.

Between Silver creek and the south branch of Ferrel brook, there is a marked sandy bar rising on its eastern face from the

480 to at least the 560 foot line, but I am not certain that it is wave-made.

When one compares the rather marked shore lines between 590 feet and 680 feet on the south, and between 620 feet and 720 feet on the north of this area, with this indistinctly marked zone between, extending down to about 500 feet on the south and to 540 feet on the north, it is evident that the sinking of the water level or the rise of the land in relation to the wave zone was rapidly accomplished. The greater number of the wave marks in this interval on the south, both as regards the cases mapped and their broader distribution in the vertical space, is taken to indicate that water action lasted there longer than on the north of the Corbeau. It is to be noted also that the large streams which traverse the northern part of this field have no deltas between 500 feet and 600 feet. They apparently extended their mouths from the deltas above the 600 foot line to those below the 500 foot line suddenly. The English river has no delta immediately below the 500 foot line, as the Big Chazy has just south of it, unless we regard that delta as partly formed also by the English river. The English river has however a delta at about 450 feet.

From a comparison of these shores lines and deltas southward throughout the Champlain valley with certain spillways and outlets between Fort Edward and Stillwater it appears that a glacial lake must have existed for a long time over the region, held in on the north by the retreating ice front and thus overflowing southward. The earliest stage of this lake is apparently marked by a spillway over the west bank of the Hudson gorge between Schuylerville and Quaker Springs. This stage of the lake is probably not represented on the Mooers quadrangle by lacustrine deposits or shore lines. The ice appears still to have covered the district.

Later the excurrent stream cleared out a drift-filled side channel of the Hudson west of Schuylerville and joined the Hudson gorge at Coveville. By this time the glacial lake appears to have extended into the Mooers district. The upper line of wave action on Cobblestone hill, and the signs of wave action rising

northwestward to the 720 foot line at Armstrong's bush are believed to have been formed at this time.

Gradually the waters at the outlet cleared out the main gorge of the Hudson and finally came to a lower level with an outlet just north of Fort Edward, establishing a level over the lake about 100 feet lower than that of the Coveville stage. At this time the shore line stood somewhere near 550 feet at the southern end of the Mooers quadrangle and at about 620 feet at the northern end of the area.

This glacial lake, which it is proposed to call Lake Vermont, endured for some time longer when the ice sheet melted out along the northern border of the Green mountains and allowed the waters to fall to the level of the sea. On account of the then low stand of the land the sea at once came in and spread as far south as Whitehall.

Before the sea came in, however, there appears to have been a stage in which the lake waters gradually fell below the Fort Edward outlet, presumably by reason of the weakening of the ice barrier on the north allowing the more or less gradual escape of the lake waters. The crowded beaches in the northern part of the quadrangle from 540 feet down to the upper marine limit near the 450 foot contour line are referred to this stage. I have described their correlation with what appear to be stream-cut terraces on the northern side of Covey hill in another paper on the ancient water levels of the Hudson and Champlain valleys.

It has been suggested by Mr Warren Upham that the ice front receded from the Champlain valley in such a manner as to allow a connection between the glacial lake in this field and one extending over the upper St Lawrence valley into Lake Ontario, previous to the invasion of the district by the sea. These beaches and possibly some of the lower ones referred to the marine stage would be thus explained but not so the cut terraces at Covey hill and the occurrence of marine shells on Mt Royal at an elevation of about 550 feet.[1]

The average inclination of these old water levels to the south is assumed to be parallel to the upper marine limit. An attempt to trace some one line of beaches proved unavailing as a test of

[1] Sir William Dawson gives both 540 and 560 feet for the elevation.

Plate 15

View of the beach at 500 feet elevation in Mooers, 3 miles northwest from Mooers Forks. Looking south

Plate 16

View looking west by north on the shore bar at 500 feet, on the headwaters of Bullis brook

Plate 17

Shore bar cut through by headwaters of Bullis brook at 500 feet. Looking north

their attitude. There are certain lines of water level, for instance that at about 500 feet between the English river and the west branch of that river, which at first sight appear to be without tilting. On going south of Wood Falls one finds the fragments of a beach at practically the same level and again farther southeast near the road from Sciota to Altona there is a large bar at this level. But when the line is followed along the international boundary, favorable slopes of the ground show equally good wave marks going up to 540 feet. The beaches are not continuous.

A conspicuous bar first noted by Dr Gilbert occurs at 450 feet on Bovington brook near West Chazy, quite well enough formed to have been made by strong waves in the sea, but it does not appear to demand stronger wave action than that formed on the face of Cobblestone hill just west of it at a much higher elevation and undoubtedly by glacial lake waters.

Lower series of beaches

The lower series of beaches on the Mooers quadrangle comprise those levels of former wave action which can be traced northward beyond the limits of the map around the northern slope of Covey hill in Canada. These wave marks are presumably marine. The data from Covey hill beyond the northern limits of this area are briefly presented in this paper under another heading. The highest level of clear wave action at that point is 450 feet above sea level. On the Mooers quadrangle wave action is traceable on the northern margin of the area in closely set ridges forming a distinct group from 540 feet down to 370 feet at the base of the hill just east of Armstrong's bush. Eastward over the area, beaches occur on exposed places, mainly low ridges or hillocks, at levels from 350 feet down to 340 feet and again near Perry Mills at 250 feet (by the contour of the map) [pl. 15].

This group of beaches can be traced from the northern limits of the map to the vicinity of the English river. Between the English river and Bullis brook west of Sciota, recognizable beaches are fewer and much less distinct as the accompanying map shows. About a mile southeast from Wood Falls the highest beach seen occurs at 500 feet according to the local contour by the map. There is a bar [pl. 16, 17] partly thrown across one of the head branches of Bullis brook at this level. East of Bullis brook and

southward to the southern limits of the map, beach ridges rib the slope at Sciota from 495 feet down to 250 feet according to the contours of the map. Beach ridges and waterworn gravels occur either side of the state road from Sciota to the vicinity of Tracy brook. At 450 feet Bovington brook, as noted by Dr Gilbert, cuts through a well formed bar with a typical under water beach slope in front of the bar. Above this level along the road to Cobblestone hill there are faint parallel lines with rather angular washed material indicative of wave action at 530, 545 and 580 feet (by the map). These higher water lines are apparently traces of the water body which sank stage by stage from the 570 foot level in this latitude to the lower series of beaches. South of West Chazy stronger and broader bars than appear on the north come into existence in a slightly overlapping or offset arrangement, which is fairly well shown by the contouring of the map just above the 420 foot line. These broader ridges are marked by minor beach ridges. East of West Beekmantown, these larger bars take on the form of definite offshore bars, inclosing back swamps. Silver creek winds its way in rectangular adjustment down the slope running part way between the bars and part way transverse to their extension where they become depressed and exhibit their offsetting. Another broad wave-heaped ridge of this character occurs south of West Beekmantown at about 500 foot elevation. West of this beach wave marks appear at about 545 feet. There is a distinct group of half a dozen beach ribs on the slope south of Silver creek from 315 feet up to 340 feet. This group of minor beach ridges extends northward and merges into the broader belt of greater vertical range north of West Chazy.

The beaches of this lower series, as a whole, are composed of highly angular materials, often flat slabs of Potsdam sandstone or angular polygonal blocks dependent apparently on the manner of fracture of the nearby underlying Potsdam sandstone derived either from ledges or the glacial drift worked over by the waves. In the northern part of the map near the international boundary, rolled and rounded pebbles aside from those in the deltas near streams as at 420 feet east of the English river, first appear at an elevation of about 350 feet on the western slope of a

low modified drumloidal hill about 2 miles northwest of Mooers Junction. The underlying glacial materials are angular rock fragments peculiar to glacial till. It is evident that long continued and effective wave action took place on the western slope of this hill. The eastern slope is occasioned by a few large boulders but without waterworn materials and without any definite signs of a beach. Another similar ridge about 1 mile southeast of that above described shows similar features except that its crest is wave-heaped inclosing a shallow lagoon between low beach ridges. Its eastern slope is wave washed. The crest is approximately at the 350 foot level.

From Sciota southward to near West Chazy there is much subrounded beach gravel along the state road at levels from 380 to 400 feet. There are also heavy beaches [pl. 18-21].

Summarizing, none of these ridges has been found sufficiently continuous and distinct from those above and below it to enable one to trace it out by walking across the area on what appeared to be a deposit made at any one time across the limits of the sheet. The attempt to show whether the beaches are still level or are tilted from their original position appeared to demand a more general consideration involving a study of the beaches north and south of the area. Similarly the distinction between beaches made by waves in the glacial lake which it is believed covered the district before the sea came in and those made by the waves of the sea has not seemed possible by means of evidence found within the Mooers quadrangle. Though as shown below there are certain details in the strength of wave action which fit in with facts farther south and confirm the view that the upper marine limit is approximately determinable.

Evidence at Covey hill, Canada. Fortunately for the geologist in this field, the critical area for the study of the shore line problems which arise on the Mooers quadrangle lies just over the international boundary in Canada. Immediately north of the abandoned Niagara known as "the Gulf," the northeastern prolongation of the Adirondacks terminates in Covey hill, whose elevation according to the United States Geological Survey is 1030 feet above mean tide level.[1] Within about 3 miles from the boundary line the ground falls off to less than 300 feet, as at

[1] Information supplied by Dr G. K. Gilbert.

Vicars. The northern slope of this hill thus stands as a self-registering nilometer of the water levels which have existed in the St Lawrence valley in contradistinction to glacial lake levels in the Champlain on the east of the Adirondacks and in the upper St Lawrence valley and over the Lake Ontario basin on the west.

The crest of Covey hill is till covered. It has already been pointed out that "the Gulf" at the western base of the hill indicates the path of a powerful torrent flowing across this spur of the mountains at the time when the ice front had receded locally as far as Covey hill, but had not retreated from its northern slope. These torrential waters held up by the ice formed a waterfall, whose cliff is now at 870 feet, and whose pool stands at 830 feet; below this is a second pool in the bottom of a chasm 160 feet deep precisely on the international boundary line. The surface of this pool, according to Dr Gilbert's observation, is 645 feet. From this point the valley opens out, the small, spring-fed stream which escapes from the lakelets turns northeastward, thence north past Covey Hill postoffice and, joining the English river, falls into the Chateaugay and thence enters the St Lawrence river at a point almost directly north of Covey hill.

From the facts shown at "the Gulf" it is evident that, when the ice front rested against the northern slope of Covey hill, the drainage at its southern base found open-air conditions of flow at a level as low as that of 645 feet. About 2 miles southeast of this lakelet, something like shore line phenomena appear on the Mooers quadrangle at 620 feet to 630 feet, a level which would not have drowned the waterfall action at "the Gulf." At an earlier stage water levels appear 100 feet higher in the northwest corner of the Mooers quadrangle; water at this level would have penetrated the chasm at "the Gulf" and entered part way between the lower and the upper lakes. At a still earlier stage there appears to have been formed a cobblestone bar with spits just west of the Mooers quadrangle at an elevation of about 810 feet (aneroid); waters at this level would have come nearly to the upper lake.

At the time the waters were flowing out of the lower lake at "the Gulf," the discharge must have taken place eastward and thence southward to the Mooers quadrangle along the 620 foot to 640 foot level, being held to this line of flow by the ice on the north

and also for the reason that the ground south of "the Gulf" along the line of the Stafford's and Blackman's rock spillways was much higher than the path opened up as the ice retreated from the Potsdam escarpment to the east of "the Gulf."

That certain shore lines on the Mooers quadrangle and the area west of it are contemporaneous with the drainage through "the Gulf" notch and thus with the ice sheet frontage against the northern slope of Covey hill, is shown by the absence of such distinct wave marks on the northern slope of the hill between the levels of at least 900 feet and 600 feet. An almost unmodified slope of till in the most favorable position for rearrangement under the action of waves or lateral glacial streams covers this important interval. The phenomena of "the Gulf" demand an ice barrier on the north to hold up the extraglacial waters so as to cause them to flow over a col in the divide between the head waters of the Chateaugay river. The water levels on the south of "the Gulf," whose range is the same as that of the depth of "the Gulf," are, it has been shown, also contemporaneous with the ice frontage in that field and therefore, I think, are demonstrated to be independent of the sea in the Champlain and St Lawrence valleys.

The intervals between signs of water level on the Mooers quadrangle thus appear to be associated with a glacial lake, sudden falls in which might arise from the opening of new spillways as a consequence of the continued retreat of the ice sheet.

There is, according to my observations, something like a periodic recurrence in the vertical interval between these water levels; thus there is, above the continuous series of lower beaches which stop off between 520 feet and 540 feet, an interval up to 610 to 620, another interval from that level to that of 720 to 725, followed by another up to 810 or 820 feet, intervals approximately 100 feet. This is I believe to be attributed to the nature of the ground about the southern end of this glacial lake in the region of its outlet.

Determination of the upper marine limit, benches and beaches on the north slope of Covey hill. The accompanying sketch map gives a general idea of the Covey hill district [*see* pl. 11]. The roads and position of villages have been traced from Walling's *Atlas of Canada.* The contour lines are mere approximations based on

aneroid readings made by myself in traversing some of the roads and the railroad shown on the map. The elevation of the top of Covey hill has been furnished me as noted by Dr Gilbert.

The crest of Covey hill is devoid of marks of water action attributable to waves or glacial streams. Toward the base of the northern slope of the hill, unmistakable evidence of water action begins to appear at about 570 feet, and from that level down to the rather rolling low ground at its base there is first a succession of benches and then of distinct beaches. These are encountered in going from Covey Hill postoffice to Vicars, from the top of Covey hill to the main road west of Stockwell, and in descending the hill by the northwest road which enters Franklin Center.

On the road to Franklin, just beyond the fork in the roads, there is a small sand flat or delta on a little stream at an elevation of 720 feet (aneroid); and again, on the same road just south of Franklin and above the point where a "dug road" comes in from the northeast, there are low, flat ridges sloping westward at an elevation between 700 feet and 800 feet (aneroid reading discredited). These are the only exceptions I noted to the general absence of water levels on this hillside above 570 feet, and these cases are of the discontinuous kind which may be attributed to temporary conditions attending the drainage along the margin of the ice sheet as the front retreated from the northern slope of the hill.

Dr Gilbert, in his manuscript notes, records a well marked beach on the road from Covey hill to Vicars at an elevation of 450 feet. He states that he noted ridges above that level, but that they lacked the element of horizontality and were hence thrown out of the evidence he sought for the determination of the upper marine limit.

In going over the hill to the west and down the road toward Stockwell, a shelving terrace is encountered at 580 feet which drops off in the form of a low cliff to a shelving flat, which joins the cliff base at 570 feet. No signs of water action in the way of waterworn pebbles are noticeable, but some form of erosion has evidently taken place at this level. Going farther down this road, the till is cut back in the form of a good bench with a cliff. The road from Stockwell to Franklin Center runs on this bench at

an elevation of about 540 feet (aneroid). This is the highest of a group of strongly developed benches which can be traced along the northern base of Covey hill for several miles. Their surfaces are frequently strewn with coarse angular blocks of sandstone, though half a mile east of Stockwell postoffice a bar at 520 feet shows coarse, waterworn material. Gravelly beaches begin in this direction at 450 feet. Above this line the materials are coarse stones. The road follows the upper ridges at least as far as Rockburn.

At Franklin Center, as indicated on the adjoined sketch map, which is designed only to show the general orientation of the roads, the 570 foot bench with a cliff cut in the till is distinctly shown. North of the main road is a succession of beaches and ridges down to at least 396 feet. All readings are aneroid compared with the top of Covey hill. First and just north of the crossroads is the crest of a bar at 480 feet, with waterworn pebbles on the base of the beach slope at 450 feet. At a slightly lower level and farther north is a weak beach ridge. North of the crossroads there is a beach ridge 430 feet at top, with waterworn gravel down its northern slope to 400 feet. This beach is confronted by a flat whose surface is at 396 feet. The upper stony ridges become stronger and more distinct toward Rockburn, beyond which point within Canada I have made no attempt to trace them.

Dr Gilbert, in his manuscript notes, placed the upper marine limit at Covey hill at 450 feet. With this decision I agree.

Taking the 450 foot line as the upper marine limit at Covey hill, the rude terraces above that level would appear to be of the nature of stream cuts partly made in the till of the hillside at the time the ice front still pressed against the base of the hill. As soon as the ice began to melt back from the hill the water which had been heretofore forced across "the Gulf" spillway would find a lower pathway about the northern base of the hill and thence into the Champlain valley. The rude beach deposits along the international boundary on the Mooers quadrangle from 540 feet downward to and even below the 500 foot contour line are the local equivalent of this state of affairs, but there probably was open water in that field.

Accepting the evidence at Covey hill for placing the upper marine limit at 450 feet, it would further appear that the beaches in this region above that level are those of a glacial lake. The evidence found in the southern part of the Plattsburg quadrangle about Port Kent seems to indicate that the upper marine limit is there to be placed at an elevation not more than 330 feet above sea level of today. On this basis plate 25 has been prepared exhibiting the shore line as it is presumed to have stood at the time the sea was at its maximum extension in the Champlain valley. This line it will be noted makes an arbitrary division of the crowded beach lines in the lower series.

As stated in another place the marine shells which occur near Mooers at 340 feet, and on the Saranac above Plattsburg at approximately the same elevation, 342 to 346 feet, prove that the sea stood as high as 340 feet at least over the northern part of the district. It is to be presumed that shells may be found as high as the marine limit in beach deposits. As yet shells have not been reported in the beaches of this district.

The upper marine limit as here placed coincides with a tilted plane passing through the 450 foot beach at Covey hill and just above the 550 foot marine shell deposit on Mt Royal. This plane intersects the delta of the Big Chazy at Mooers Forks, and the heavy beaches south of Sciota [pl. 18-21] at about 400 feet; it also passes beneath the rock cliffs from the waste of which these beaches are in part built [*see* pl. 22-24].

Marine invasion

It has long been known that on the disappearance of the ice sheet from the St Lawrence and Champlain valleys the sea covered the floors of these valleys at least as high as the localities at which marine shells have been found in the clays and sands laid down at that time. Opinion has differed among geologists only as to the depth to which the land in various parts of this portion of the continent was then submerged. The character of the fossil shells, the fact that many of the species are still living in the St Lawrence gulf or in the adjacent waters of the Atlantic coast show that these animals found their way into the Champlain valley from the north or northeast. The

fossil shells are found along the New York side of Lake Champlain at least as far south as the ruins of the old French fort on Crown Point peninsula. The marine waters probably extended as far south as Whitehall; and as will be shown in another report on this special subject that there was no connection by the marine waters southward through Wood creek with the sea at the mouth of the Hudson river at this time, the land on the south being elevated very much in the same proportion as the land in the upper St Lawrence valley was depressed below sea level.

Marine deposits

There is difficulty in distinguishing the marine deposits of this area from those made by the waters of the glacial lakes. The sole satisfactory local criterion is the presence of marine shells or other fossils in the oceanic series. As already indicated these deposits occur in the low grounds. On plate 25 the shaded area shows the horizontal extent of the marine deposits according to the determination of the upper marine limit which has been made in this report. In general the marine deposits on this area are stony modifications of the glacial deposits, largely modified till, worked over by waves and currents. The effect of wave action has been to arrange the drift in the form of beach ridges, and waves and currents together have produced bars of gravel or flats of sandy materials frequently changing to gravels or coarse, bouldery deposits. The accompanying map [pl. 26] is not made to show the distinctions between these various phases other than to delineate the recognizable beach ridges. Here and there a plain of sand or gravel marks the delta of a stream as at Mooers and Mooers Forks. The deposits of undoubted marine origin within the area are only a few feet in thickness. Some parts of the submerged area exhibit morainal deposits apparently without alteration as north of Mooers and east of Sciota. The finer waterworn deposits are best developed along the courses of the streams and are thus to be regarded as rehandled detritus alternately deposited in deltas and thus carried downward about the mouth of the stream as the land rose above the sea.

Deltas at old sea margins. The larger streams have at certain levels well marked deposits of gravel and sand along their courses, evidently deltas built during the time of submergence.

The English river exhibits such a deposit about 2 miles northwest from Mooers Forks. The stream now makes a turn about the northwestern margin of this deposit. At one time, the stream passed to the east of the delta making a deep trench shown by the contours on the map.

The Big Chazy river has a small delta above Mooers Forks mainly developed in the triangular area between this stream and its north branch. The sands of this deposit extend up the valley to about 500 feet above sea level. Along the eastern margin of the delta from 400 feet to about 440 feet the surface is faintly marked by beach and wave-cut lines.

At Mooers there is another delta on the Big Chazy, whose surface is at 280 feet.

Bullis brook exhibits a slight delta at 300 feet on the south of Mooers and Shedden brook, also has a slight delta at about 280 feet elevation.

The small streams on the south to the limit of the map show no marked signs of their former local entrance into the sea.

Clays. The area mapped on this quadrangle lies mainly to the west and above the typical zone of marine clays which borders the present shores of Lake Champlain. The clays however appear along the course of Big Chazy river at Perry Mills in the northeast corner of the area and are said to underlie some of the swamps in the low grounds, probably as high as the 240 foot contour line in the region north and east of Mooers. Clays also appear in the banks of Bullis brook near its junction with the Big Chazy river. There is another locality on the north bank of the river about 1½ miles east of Mooers. At this locality clay has been worked in recent years in a small way for brickmaking. The clay is decidedly sandy and is overlain by sands representing the outer margin of the Mooers 280 foot delta, a deposit of which the clays are probably an essential part. They are not generally exposed at the surface west of Perry Mills. For an occurrence of early stratified pebbly clays *see* note on p. 53.

Marine fossils. Postglacial marine fossils were found during the course of this survey at only three points within the area of the map. The excavations made for the State road from West Chazy to Sciota in 1903 gave numerous shallow sections in the beach gravels between the 300 foot and 400 foot contour lines, but no fossil shells were seen in several thousand feet of such exposures. A few shells of *Macoma groenlandica* were found however in a borrow pit in the sand hill on the west bank of Tracy brook, where the road crosses that stream at 300 feet of elevation.

An excellent exposure of fossiliferous sands and some clay was found at the bend of the Big Chazy about 1¼ miles below Mooers Forks. The marine deposits here rest on an arenaceous boulder clay without the interposition of barren sands or clays which might be attributed to a glacial lake. The deposits are exposed on the west side of the neck of land near a large outcrop of the Potsdam (Saratogan?) sandstone lying in the middle of the stream. The bank is gradually receding here under the attack of the river. At about 340 feet above tide, 3 or 4 feet of fine marine sands, including a thin, underlying clay, contain numerous shells of *Saxicava rugosa, Leda arctica,* a few valves of *Yoldia* sp., and shells of *Balanus* sp. Many of the molluscan shells show both valves in the attitude of growth. The deposit is overlain by coarse gravels, evidently a part of the old river bed when the Chazy flowed at a higher level.

Fossil shells, apparently *Macoma groenlandica,* were also seen in a trench in gravels at a house by the spring west of the schoolhouse which stands about 1 mile west of Perry Mills, at about 300 foot elevation.

Mr William D. Stevenson, United States customs officer at Mooers Junction, stated that some 15 years ago he saw shells taken from a well on the McDowell place at the depth of about 8 feet. This locality is at the railroad junction, where the surface of an ancient delta of the Big Chazy is approximately at 280 feet.

The lack of recent excavations prevented undoubtedly the finding of shells in many parts of the low ground along the eastern part of the area.

Just over the international boundary, north of Mooers Junction and about 1½ miles south of Hemmingford, Can., at an

elevation determined by the aneroid barometer to be 270 feet, abundant shells of *Saxicava rugosa* were found in a fine state of preservation in gravel at depths from 18 inches to over 3 feet below the surface. Many of the shells were standing in attitudes of growth in the spaces between the pebbles. The deposits were very rudely stratified.

The discussion of the bearing of these and other shell deposits on the New York side of Lake Champlain is given in full in my report on the marine submergence.

RECENT CHANGES

Since the glacial deposits were strewn over this district and the old shore lines marked out by waves, it is evident that the land has risen in relation to the sea. According to the data gathered in this survey, this elevation amounts to about 450 feet along the international boundary, being somewhat less in the southern part of the area because of the tilting to the south. There are reasons for believing that this change of level is still in progress but no local evidence of it has been observed.

The exposure of the rocks to the atmosphere in postglacial time has produced a slight amount of weathering and consequent disintegration. In many places over the flat rock spillways the Potsdam sandstone has broken down, affording loose white sand or white quartz pebbles but always in very small quantities. A more noticeable effect in this area has arisen from the action of frost in prying loose the angular joint blocks or slabs of the rock. On the whole the drift strikes an observer from the southern part of the glacial field as little altered by weathering but the resistant character of the Potsdam sandstone which forms so large a part of the coarse material tends to highten this impression. The amount of work done by glacial torrents and by waves gives in this region a far longer vista of late glacial and postglacial time than does the degree of weathering.

Streams and stream deposits

All of the streams of this quadrangle, except the brooks flowing down the south slope of Rand hill in Beekmantown, discharge across the zone of abandoned and elevated beaches. The courses of the streams thus present that irregularity which arises from

Plate 18

View looking north along the uppermost beach ridge shown in plate 19 south of Sciota

Plate 19

Looking east over the coarse beach ridges built along the shore south of the Sciota cliff

Plate 20

Landward slope of one of the coarse beaches, 2½ miles south of Sciota

Plate 21

View looking north along the less developed beach lines south of Sciota

Abandoned sea cliff in Potsdam sandstone, 2 miles south of Sciota, showing blocks fallen from cliff. Looking west

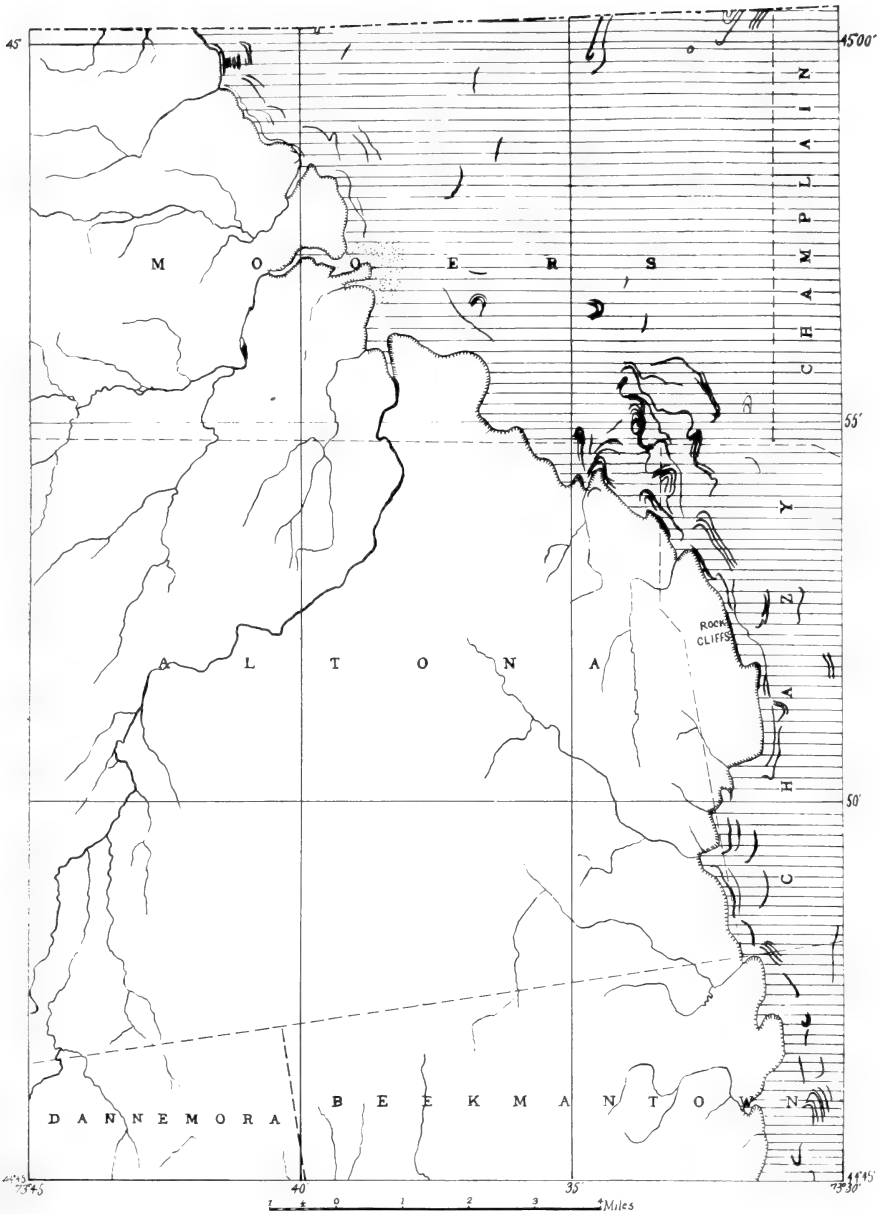
Plate 23

Upper part of the old cliff south of Sciota shown in plate 22

Plate 24

Looking south along abandoned sea cliff in Potsdam sandstone, 2 miles south of Sciota

Plate 25



Sketch map of Mooers quadrangle showing extent of submergence beneath the sea (horizontally lined). The curving lines in submerged area represent beaches and bars made during the regression of the sea

their having been extended from low to lower grounds with the recession of the ice to the northeast and the withdrawal of standing bodies of water from the ancient shore lines. The streams have thus been compelled to find their way from point to point by flowing over and out through the lowest path in the surface materials. The head waters of the north branch of the Big Chazy and the English rivers appear to flow in rock valleys older than the last ice epoch.

The 500 foot delta on the north branch of the Big Chazy river received contributions from both of these streams. By a shallow trench about ¾ of a mile in length the English river might now be diverted into the north branch of the Big Chazy river across the upper part of this delta. Two miles northwest of Mooers Forks, the English river has cut its channel around the northwestern margin of what was probably a delta at the 420 foot local water level. First the stream appears to have escaped eastward by a dissection of this deposit.

The Big Chazy river also exhibits evidence of having shifted its course during the changes of level which have raised the old ocean bottom above the sea level. From Thorn there is a broad stream channel from 20 feet to 40 feet deep, leading northeastward to the Sperry brook depression about half a mile west of Mooers Junction. The contours of the map fail to show this channel. At Thorn the bottom of the channel is about 20 feet above the present bed of the river. When this channel was used, the Big Chazy must have flowed north of Mooers Junction along the northern side of the 280 foot delta at that place.

The river appears also to have flowed temporarily along a course half a mile north of its present channel at Mooers Forks, as is shown by the swampy channel north of the railroad curve near that place.

In many places as on the road along the eastern bank of the river from Altona to Wood Falls, the Big Chazy river bed, with characteristic torrential deposits, extends widely on either side of the present channel. The same remark is applicable to portions of the north branch of the river and to the English river. The streams are evidently in the process of lateral shifting, and at the same time they are sinking deeper into the drift

deposits over which they flow. In several places, as at Wood Falls, the rivers have become fixed in rock gorges; in other places, where recent shifting has caused them to cut deeply into the banks, the streams are on or near the bed rock and are soon likely to become fixed in their course. The bank at the sharp bend between Thorn and Mooers Forks on the Big Chazy is being undercut on the north side, but the stream is here partly on bed rock.

Bovington brook, near West Chazy, presents a good example of a small stream which has been extended as the land rose above the old water levels with their beach barriers. At about 450 feet the stream passes by a small cut through a barrier beach thrown across its path. Corbeau brook, where it traverses the beaches on the 400 foot contour line, has swept these deposits away for several yards south of its present channel.

Wind-blown sands

Wind-blown deposits of sand in the form of ancient dunes of small extent occur south of the Big Chazy river in the southeastern corner of the town of Mooers at an elevation between 240 feet and 260 feet above sea level. They appear to have accumulated from the deflation of the surrounding sandy tracts. Two such areas of blown sand are shown on the map. That on the boundary line between the towns of Mooers and Champlain is the more conspicuous dune; it has been resorted to as a source of fine sand. Except for the blowing of sand about the artificial openings in the soil covering of the deposit, the sand appears not now to be blowing, and it does not seem likely, with the generally thick grass coating of this region, that these deposits will prove detrimental to farm lands by their extension.

Dunes have not been recognized in association with the ancient shore lines at higher levels within the area, nor are ancient or existing dunes observable about the sandy deltas along the Chazy river and its branches.

Swamps

The fresh-water vegetal accumulations within the area are extensive, particularly in the low grounds and as narrow strips between and behind the low gravel and shingle ridges in the zone

of beaches. Besides those shown on the map there are scores of narrow swampy strips too small to be mapped. Considerable tracts belong to the group of wet woods rather than swamps. About 1 mile east of Wood Falls there is a depression occupied by a dense growth of tamarack with the usual swamp conditions. Shallow swamp growths margin many of the streams in northern Altona and Mooers; particularly are these swamps noticeable at the elevation of 500 feet. Abandoned stream beds also give rise to small narrow swamps, as in the example parallel to the Rutland Railroad tracks northeast of Mooers Forks.

Most of the larger swamps in the low grounds appear to occupy the broader depressions in the old sea bottom, where the slopes are too gentle for the existing streams effectively to drain the area. Whether or not the tilting of the district in postglacial times has had any effect on the formation of swamps, does not appear from an examination of their development in relation to north and south flowing streams. The fact that the smaller swamps are mainly shallow, and that they exhibit the habit of climbing the slopes of stream bottoms, offsets perhaps the effects of a displacement of the surface. It should be noted however that a large swamp tract appears along the course of the Big Chazy river on the eastern border of the area mapped just where the river turns to a northward course. The valley is broad and open here and becomes narrower near Perry Mills.

Peat. The swamps on this eastern margin in the town of Champlain, including a large one on the adjacent Rouse Point map to the eastward, are said to be underlain by extensive peat deposits.

SUMMARY OF PLEISTOCENE HISTORY OF THE AREA

Definite traces of glaciation anterior to the latest or Wisconsin epoch have not been recognized. Earlier glacial deposits might well have been scoured away in a region which received the brunt of ice action as the Wisconsin ice sheet pressed on and rose over the northern slope of the Adirondacks. A small deposit of very fine grayish sandy clays, with whiter bands of a more silicious character in the north bank of the Big Chazy, about 1 mile above Mooers Forks and now overlain by boulder clay is the only as yet discovered deposit intermediate in age

between the clearly recognizable Wisconsin drift and the ancient Paleozoic rocks. These clays are evidently nonglacial, but whether they are Pleistocene or not is undetermined. The clays contain Potsdam pebbles up to 3 inches in diameter, of angular shapes and free from striae of any sort. Floating ice appears to be demanded for the distribution of such pebbles in stratified clays, and it is possible that the deposit is Pleistocene in age. The top of these clays is approximately 400 feet above the present sea level.

The principal surficial glacial deposits of the region pertain to the latest stages of the ice sheet and were formed at a time when the country to the southward was free from ice. They are undoubtedly contemporaneous with many of the deltas and lake beaches about the southern borders of the Adirondacks, and with the water levels in the upper Hudson valley.

As the ice front receded from the foothills of the Adirondacks, recessional frontal moraines were formed, and, when the ice had receded far enough to permit of the existence of northward flowing streams having a considerable volume of water, this drainage as well as that from the ice became organized in torrential streams, escaping along the ice margin toward the east into a glacial lake covering the site of the present Lake Champlain. These waters flowed across the "flat rock" or spillway at "the Gulf" on the international boundary. As the ice retreated, but before it retreated from the north slope of Covey hill, it seems to have opened a passage just north of the boundary and east of "the Gulf," so that the waters passing through "the Gulf" for a time entered a glacial lake near the mouth of "the Gulf." Eventually the ice melted out from the St Lawrence valley so as to permit the ingress of sea water, whereon strong wave action took place at what is now an elevation of 450 feet on the north slope of Covey hill. Southward wave action is found above and below this limit. That above is referred to a glacial lake, that below mainly to the sea. On the Plattsburg quadrangle, to the southward, there is a cliff with strong delta building at about 330 feet, phenomena which are taken to mark the marine limit at that place. The marine limit fixed in this manner is interpreted to indicate a rise of the old sea level on the north at the rate of 4.41 feet to the mile. This would place the marine limit on

the northern margin of the Mooers quadrangle at about 450 feet and on the southern margin of the area at about 370 feet.

Such a tilted plane agrees very closely with the rate of falling off in elevation of the fossil shell localities from Montreal to the southernmost localities known on the New York shore of Lake Champlain.

The land in this district was at an undeterminable elevation during the time it was ice covered. When the ice began to disappear from the region a glacial lake formed along its front in the Champlain valley and it is evident that the land in the southern part of the State was higher than it is now in relation to the Champlain district. During the existence of this glacial lake, changes of level apparently were in progress, but they can not well be discussed without more detailed reference to the glacial retreat on the south than can be given in this local report.

After the sea came in from the north, the land at least began or perhaps continued to rise gradually, causing the sea to retreat from the area. As the land rose, the streams extended their courses, building noticeable deltas at particular levels; and gradually the existing state of physical features of the area was established. There are some reasons for believing that the changes of level are still in progress, though no local measurement of such a movement has been detected.

The general discussion and a more complete account of the glacial lakes and the marine submergence in this area and throughout the Hudson and Champlain valleys will be found in Museum Bulletin 84.

EXPLANATION OF THE MAP OF THE MOOERS QUADRANGLE

The southwestern part of the Mooers quadrangle everywhere above the elevation of 900 feet, and in many places from about 700 feet upward is more or less thickly coated with typical till, here and there taking on a hummocky aspect where thickened in the manner indicative of recessional moraines. There is but one stratified sand deposit in this field, that near Alder Bend.

The mapping of the general sheet of surficial deposits below the limits of this clearly demonstrable unmodified glacial drift must be regarded as provisional. After the work was begun

what at first sight on the basis of long familiarity with glacial drift in other districts was taken to be unaltered glacial till was ascertained to be till partly modified by the action of waves or currents. Thus near Norwood, on the west of this field, marine shells occur at the depth of over 2 feet in what at the surface has all the appearance of glacial till, but which in section shows that it must be regarded as a rubbly layer worked over without distinct stratification or even rounding of the constituent rock particles. Usually the action of the sea on these stony tills has been to leave the surface of the deposit strewn with many small blocks of rock, which appear to have accumulated on the surface as the result of the washing away to lower grounds of the finer sands and clayey particles of the superficial layer in which the stones were originally embedded. The larger glacial boulders are seldom moved far and often project from the soil as in the case of ordinary till areas.

The area mapped as "Undifferentiated glacial deposits superficially worked over by waves and currents" is of the above described character. Beach lines, and bars of wave-heaped rubble are common in the district as shown on the map. This belt rises to a somewhat higher elevation on the southern border of the area than it does on the north.

Lying above this wave-modified district there are in the northwestern part of the area very similar deposits only less distinctly reworked except along certain ancient water levels. The distinction between the two areas is difficult to make and there are large areas in both fields which I am sure are identical in topography, in composition of the drift, and in structure; yet one distinctly gets the impression in passing from the low grounds to the upland portion of the district on going above an elevation of from 450 to 500 feet, that he is passing from a zone of largely water-laid materials to a region of till. The demarcation in the field between these two areas of more or less modified deposits is usually very vague. I have drawn it on the map at about 500 feet in elevation in the northern part of the map because above that line the chief characteristic of the lower belt of materials—the presence of beaches—is usually wanting.

Another plan of mapping would have placed the area covered by glacial lakes under one color and that later covered by the sea under a different color but this would have resulted in an equally arbitrary division of the deposits of the area.

The pattern for beaches and bars has been applied equally to the belts of rounded pebbles and angular stones, to the coarse bouldery deposit of Cobblestone hill and the sandy beaches. Some of the lines of supposed water level above the 500 foot line in the northern part of the area are also marked by the same pattern and color.

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INDEX

The superior figures tell the exact place on the page in ninths; e. g. 16^3 means page 16, beginning in the third ninth of the page, i. e. about one third of the way down.

Alder Bend deposit, 15^1.
Altona deposit, 15^6.
Altona Flat Rock, 16^3, 18^3–21^2.
Armstrong's bush flat rock, 21^6–22^3.

Baldwin, S. P., cited, 57^4.
Barnard, E. C., cited, 13^7.
Beaches, location and description, 26^6–46^6; upper limit, 29^6–31^4; upper series, 31^5–39^4; lower series, 39^5–46^6.
Bibliography, 57^3.
Big Chazy river, 51^3, 51^5.
Blackman's rock, 16^5, 21^2.
Bovington brook, 52^8.

Chalmers, R., cited, 57^4.
Clays, 48^6, 53^9.
Cobblestone hill beaches, 32^7–39^4.
Corbeau brook, 52^4.
Covey hill, Gulf at, 22^3–24^8; evidence at, 41^8–43^8; determination of the upper marine limit, benches and beaches on the north slope of, 43^9–46^6.
Cushing, H. P., cited, 4^3, 57^5.

Dawson, Sir William, cited, 38^9.
Deer brook deposit, 15^8.
Deltas, contemporaneous with ice fronts, 14^6–15^9; at old sea margins, 48^1.
Drift, glacial, 4^9, 9^3; of Wisconsin epoch, 5^8.
Drumlins, probable, 10^8–11^1.
Dunes, 52^8.

Emmons, Ebenezer, description of The Gulf, 22^6; cited, 57^5.
English river, 51^3.
Eskers, 13^3.

Flat Rock system, 17^7–24^8.
Flat rocks, 16^1–24^8.
Fossils, marine, 49^1–50^3.
Frontal moraines, 11^2–13^3.

Gilbert, G. K., acknowledgments to, 4^6; cited, 13^7, 16^9, 18^8, 29^1, 41^9, 42^4, 44^1, 44^7, 45^6; examination of The Gulf, 23^2.
Glacial deposits, 9^3.
Glacial drainage, 13^3.
Glacial erosion, 8^9–9^2.
Glacial striae, table, 5^8–6^4; interpretation of, 6^4–8^8.
Glacial striation, 5^5.
Gravel deltas, 14^9.
Great Flat Rock System, 17^7–24^8.
Gulf, The, at Covey hill, 22^3–24^8.

Hayes, Isaac L., cited, 29^3.

Ingraham esker, 13^6.

Jericho rock, 16^4.
Jericho spillway, 17^4.

Lake and marine deposits, 25^4–53^7.
Lake Vermont, 38^3.

Map of the Mooers quadrangle, explanation of, 55^7–57^3.
Marine deposits, 47^3–50^3; late, 25^4–53^7.
Marine fossils, 49^1–50^3.
Marine invasion, 46^7–50^3.
Mooers quadrangle, area included, 4^1.
Moose rock, 16^4.
Moraines, frontal and recessional, 11^2–13^3.

Peat, 53^7.

Pleistocene history of the area, summary of, 53^7–55^7.

Post-Wisconsin lake and marine deposits, 25^4–53^7.

Recent changes, 50^8–53^7.

Recessional moraines, 11^2–13^3.

Sand deltas, 14^9.

Sands, wind-blown, 52^5.

Shore lines of the area, 26^6–46^6.

Small rock exposures, 24^9–25^3.

Spillways, 13^3; and the flat rocks, 16^1–24^8; Jericho, 17^4.

Stafford's rock, 16^5, 21^4.

Stevenson, William D., cited, 49^7.

Streams and stream deposits, 50^9–52^4.

Surface deposits of area, 4^9–5^3.

Swamps, 52^9–53^7.

Till of the lowlands, 10^1.

Till of the uplands, 9^5.

Upham, Warren, mentioned, 38^7.

Wind-blown sands, 52^5.

Wisconsin epoch, 5^8.

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GEOLOGY 8

ANCIENT WATER LEVELS

OF THE

CHAMPLAIN AND HUDSON VALLEYS

BY

JAY BACKUS WOODWORTH

	PAGE
Preface	65
Introduction	66
Chapter 1 Physiography of the Hudson and Champlain valleys in relation to the control of glacial products	68
2 Retreat of the Wisconsin ice sheet from eastern New York	87
3 Glacial deposits of the middle Hudson valley	115
4 Glacial deposits of the upper Hudson valley	134
5 Retreat of the ice sheet in the Champlain valley	152
Chapter 6 Valleys of Lake George and Wood creek	165
7 Deltas and shore lines of the Champlain valley	168
8 Larger glacial lakes of the Champlain and Hudson valleys	175
9 Larger glacial lakes of the Champlain and Hudson valleys (continued)	190
10 The marine invasion	201
11 Comparisons and conclusions	223
Bibliography	246
Explanation of plate 28	254
Index	260

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PREFACE

Several years ago a preliminary study of the Hudson-Champlain valley excited my interest in the historic problems involved in its Quaternary geology. The contributions published at that time were recognized as a very imperfect presentation of the subject and the importance of more extended and detailed investigation was strongly felt. Therefore, as soon as an opportunity was afforded in the service of the State, the aid of an expert in Pleistocene geology was invoked to take up the inquiry in detail and carry it to a conclusion. We had the good fortune to secure the services of Prof. J. B. Woodworth of Harvard University and he has carried out this plan with thoroughness while Dr. G. K. Gilbert has kindly given the use of his notes, based on several seasons of work in the St Lawrence valley. The following report is, therefore, a summary of Professor Woodworth's results obtained from 1900 to 1903, prepared after extended consultation with Mr Gilbert. While much thorough work has been done, the area is so vast and the details so complex that the report can not be regarded as final, specially many details of evidence lie beyond the national boundary. It is, however, certain that many important observations have been made, the conclusions from which constitute a substantial addition to our knowledge of Pleistocene geology.

F. J. H. Merrill

INTRODUCTION

This report relates to an area whose Pleistocene history, though among the earliest to attract attention in this country, has remained but vaguely known and has been often interpreted as supporting contradictory views. The prevalence of clays in the Hudson valley and the occurrence of terraces early led to the general conception of its having been a marine strait connecting the St Lawrence valley with the Atlantic on the south during the Champlain period of Dana's chronology, and of its elevation and denudation during the succeeding Terrace epoch of that geologist. Of late years the very considerable enlargement of our knowledge concerning the diversity of the glacial period and the recognition of the manner in which gravels, sands and clays associated with retreating ice sheets have been laid down have so far modified earlier opinions concerning the history of other fields, that the state geologist, Dr F. J. H. Merrill, decided to undertake a survey of the glacial deposits of this region for the purpose of obtaining the information which it might give. One of the most important questions which it seemed the region might be expected definitely to determine is that of the extent of the marine submergence which followed the withdrawal of the ice sheet from the Hudson and Champlain valleys; to the solution of this question the data set forth in this report are mainly contributory.

For the better understanding of the conditions of deposition of the glacial deposits the physical geography of the region anterior to the last ice advance is briefly set forth, so far as it is at present understood. To a limited extent the phenomena of the adjacent regions in New England, New Jersey and Canada have been taken into consideration where they appeared to throw light on the problems of this district.

The investigation has been carried on for the most part as a reconnaissance of varying degrees of detail with reference to the main problem in hand, points being sought for examination which promised to be of critical value. It will thus appear when the areas are mapped in detail that many interesting and perhaps important facts have not been seen. It should be stated that the

work began at the mouth of the Hudson and was carried northward. At the beginning of the work in the Hudson valley the contoured maps were relied on for obtaining the elevations of the deltas and terrace deposits; later in the Champlain valley the use of the aneroid barometer was availed of in checking data of the same sort and for getting elevations where this mapping has not yet been extended. More precise and satisfactory methods of measurement would have more than doubled the length of time which the work has taken. The field work was mainly done during the summer seasons of the four years from 1900 to 1903 inclusive.

After work in the Champlain valley had been begun by the writer, Mr G. K. Gilbert of the United States Geological Survey, who had previously made an examination of the country from Lake Ontario around the northern slopes of the Adirondacks into the Champlain valley as far south as West Chazy, generously offered to the author through the state geologist the results of his investigation. I have made the freest use of these notes both in the search for localities and as a check on my conclusions, and particularly have I been guided by Mr Gilbert's observations and conclusions in regard to the fixation of the marine limit on the northern side of Covey hill in Canada. The placing of the marine limit from that point southward, however, is entirely on my own responsibility and this distinguished geologist is in no way involved in any mistakes which I may have made in my endeavor to determine the extent, the elevation and the degree of tilting of the ancient water levels described in this paper. In this report no use has been made of the data from the northwestern slope of the Adirondacks other than to include a record of the fossil shells found near Norwood, N. Y. Special acknowledgments are due to Dr F. J. H. Merrill, who has in many ways both in the field and in the office contributed to the work of the author. I have also to thank the officers of the Geological Survey of Canada for numerous kindnesses in the granting of information and guidance, and to Prof. A. P. Coleman for giving me the advantage of his greater experience with ancient shore lines by personally visiting with me some of the critical areas of northern New York.

Chapter 1

PHYSIOGRAPHY OF THE HUDSON AND CHAMPLAIN VALLEYS IN RELATION TO THE CONTROL OF GLACIAL PRODUCTS

PHYSIOGRAPHY OF THE HUDSON VALLEY

The valley of the Hudson river, from the point of view of the stream bearing that name, is a geographic group of drainage slopes whose axial trough, if we except the Adirondack portion of the river, has a nearly north and south direction, traversing a geologic area of variable structure formed of rocks of widely different ages in its various parts, and having different degrees of topographic development. The order and structure of the rocks of its valley have long been portrayed on the geologic maps of the State, and the contour of the land forms bordering the river are now faithfully delineated on topographic maps, but the precise history of the origin of this river has not been determined. The reader must, therefore, be content with a statement of the main facts in the form and cross-section of this valley and it is important that these features should be understood in following any attempt to unravel the Pleistocene history of the valley, particularly in relation to its occupation by the last ice sheet and to the retreat of that ice from eastern New York and the subsequent invasion by the sea of at least the neighboring Champlain valley.

For the greater portion of its length, the Hudson valley consists of a gorge within a valley. Both the valley and the gorge vary so greatly in minor detail from point to point that it is desirable first to generalize the parts in which the valley, as a whole, has something like a characteristic geologic and geographic expression. From this point of view there are four longitudinal divisions of the Hudson valley each with a landscape somewhat peculiar to itself.

Longitudinal divisions of the Hudson valley. The four segments of the Hudson valley above referred to comprise two regions of mountainous relief and two of lowlands, one of the latter being relatively roughened by somewhat advanced dissection.

The first of these segments, including the source of the river, embraces the course of the Hudson within the Adirondack region, which part, for convenience of description, will be called the Adirondack-Hudson river. It is a region of the most ancient rocks in the State and of the highest relief. With this stream, this report is only incidentally concerned.

The second segment includes the river from its point of emergence from the southeastern base of the Adirondack mountains to the northern portal of the Highlands in Dutchess and Ulster counties. It is a lowland region of ancient Paleozoic strata. It is divisible into two segments for convenience of treatment, an Upper and Middle Hudson valley. In this report the Upper Hudson is meant to include the valley from the head of tide and the

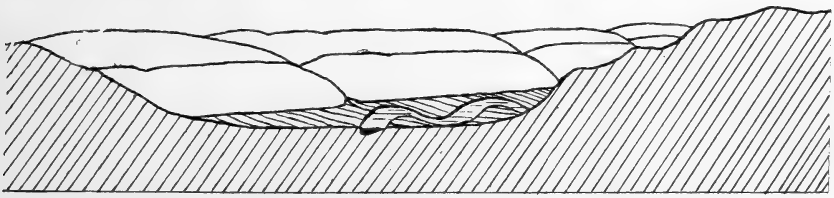

Fig. 1. Early Cenozoic stage of the Hudson valley. The river is at or near base level; it has widened out the rock bottom of its valley to form a narrow plain 2 to 3 miles wide. The stream is probably meandering and more or less alluvium sheets over the bed rock.

recent delta of the river near Troy to the base of the Adirondack mountains. The term Middle Hudson applies to the valley from the head of tide to the northern edge of the Highlands.

From the point of view of the Pleistocene deposits which the Upper and Middle Hudson valleys exhibit the region may be divided into (1) the Fort Edward district on the north, in which the history has several features in common with the Champlain valley on the north; (2) the large tract in which both banks of the river are bordered by the newer brick clays from immediately south of Fort Edward to probably the vicinity of Rhinebeck; (3) the Poughkeepsie district, in which the latest clays are wanting, extending from somewhere north of Staatsburg and the southern limits of the Albany clay district as far south as the mouth of Wappinger creek and the northern part of Newburg, where older clays begin to be heavily developed; (4) the Newburg district, extending from the last southward to the Highlands.

From the point of view of the larger features of relief, this second segment of the Hudson valley is marked by the two great valleys into which it opens on the west along the strike of the Hudson shales and sandstones, the one in the valley of the Mohawk between the Adirondacks and the Catskills on the north, and the other that of the Walkill between the southeastern border of the plateau region and the Highlands on the south.

The third division, the shortest of all, comprises the Highland canyon of the Hudson. It is a region of moderately high relief, comparable in geologic structure to the Adirondack region. This portion of the river valley will be referred to as the Highland-Hudson.

The fourth segment of the river includes the region south of the Highlands to the sea. It is a region of ancient and metamorphic Paleozoic rocks on the east and of mainly Triassic rocks on the west. It may for convenience be known as the Lower Hudson.

For geologic reasons it is convenient to recognize in an ancient now submerged channel traversing the continental shelf to the southeastward of New York harbor a possible fifth segment of the Hudson valley, which may be termed the Submarine Hudson, but to what extent this is excavated in bed rock is not known.

At the northern border of the Fort Edward district, two narrow defiles unite the Hudson valley with that of Lake Champlain; one of these is occupied by Lake George; the other, the valley of Wood creek, directly drains the northern half of the Fort Edward district into the Champlain valley.

The divide between the Hudson waters and those of Wood creek east of Fort Edward is 147 feet above sea level. A depression of 200 feet in the region between Albany and the St Lawrence river would convert the Hudson and Champlain valleys into a navigable strait having a depth sufficient for the largest vessels. A depression of 150 feet at Fort Edward and northward over the region to the St Lawrence and an elevation of an equal amount at New York city would reverse the flow of the Hudson in the lower, middle and upper sections and turn the drainage into the St Lawrence gulf.

Gorge of the Hudson. The Hudson river flows in a gorge of more recent age than its valley proper. The gorge, widened out into a well opened valley in the region of the Tappan Sea, is usually elsewhere steep sided, and throughout the middle and upper segments of the river it has a singularly uniform width and hight of wall above sea level. From the head of tide near Troy the rock floor of this gorge is, except for a few islands, below sea level, thus converting the river from near Albany to the sea into a fiord. As this portion of the floor of the gorge is now and has been for some time in the past receiving sediments, its exact depth below sea level is not known.

Beginning on the south, this gorge is believed to be traceable seaward in the so called submarine extension of the Hudson. Between the 100 and 300 foot fathom lines, the outer, deeper part of

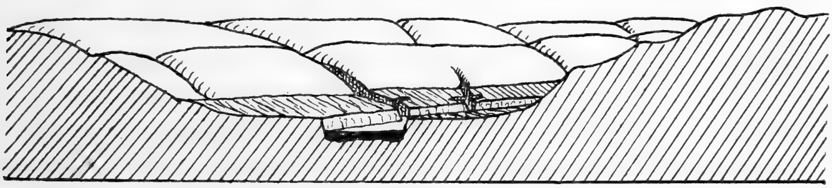

Fig. 2. Late Cenozoic stage of the Hudson valley. The river with the surrounding region has been uplifted an undetermined hight above its old base level; the river has cut a deep gorge to or near the new base level; the side streams have cut lateral gorges, and the surface of the rock terraces has become roughened by incipient dissection. Approximate preglacial condition of the Hudson river valley.

the gorge attains a depth of 452 fathoms. If the view be accepted that this part of the gorge has been excavated by the river when the land was higher than it now is, it is necessary to admit that the coast has recently stood 2700 feet higher in relation to the sea. This elevation, if it can be shown to have taken place during the Pleistocene epoch, must have had important consequences in the distribution of glaciers and their deposits during epochs of glaciation and in the work of streams in the interglacial epochs. Not only the exact geologic epoch or epochs in which this submarine gorge has been excavated is in doubt, but its origin as a subaerial phenomenon has been disputed by eminent writers on the subject of the topography of the continental shelves of the continents.

Remarkable examples of these submarine gorges exist on the east shore of the Atlantic ocean off the mouth of the Congo river,

and in the Gulf of Cape Breton, off the Côte des Landes, France, in such relations to submarine currents as to favor the hypothesis that these channels are unfilled portions of the coastal plain kept open by currents which prevent deposition along the line of these gorges. What seems to be to some writers an unanswerable confirmation of this view is the well marked gorge traversing the delta of the Rhone in Lake Geneva and that of the Rhine in Lake Constance. In the case of these lakes it is impossible to assume since the modern deltas began to form that the rivers flowing through the lakes have by uplift of the lake bottom been enabled to dissect their deltas; it is more reasonable to suppose that the configuration of the outer part of the delta in each case is due to causes now in action. Forel notes that the amount of sediment carried out over the bottom at the mouths of these rivers is too great, and that the process has been carried on for too long a time to permit any antecedent topography to remain. In his opinion these "sublacustrine ravines" are the result of erosion now going on and prove the existence of currents in the bottom of the lakes. He attributes the excavation to the lower temperatures of the river water charged with mud as compared with the temperature of the lakes. In the case of the Congo submarine channel, Buchanan has noted the occurrence of a lower, inflowing salt current in the river preventing in its course the deposition of sediment. Suess claims that in this case it is not so much that the canyon has been excavated as that the sediments have been laid down either side of it, thus building up the continental shelf and leaving a gorge in the path of the inward moving, bottom current of sea water.[1]

It must be admitted that in the case of the submarine Hudson gorge no facts have heretofore been observed on the neighboring land which demand in postglacial times so high an elevation of the coast as does the gorge itself when regarded as a true river-cut gorge. The depth of the bed rock in the Hudson river between New York city and the Highlands would be, if known, a much

[1] For literature on the subject consult Suess, La Face de la Terre, v.2, 1900, p.853–56, with references to papers by Lindenkohl, J. D. Dana, G. Davidson, F. A. Forel, Eberhard Graf Zeppelin, Duparc, Delebecque and others.

more accurate index of the elevation of the coast in recent times than the measured depth of a channel whose origin is subject to some doubt.

The most important light from the immediate vicinity of the mouth of the Hudson concerning high elevation has been presented by Veatch[1] on the basis of borings made in the glacial deposits of Long Island. An elevation of at least 250 feet is indicated previous to the deposition of the Jameco gravels, beds seemingly near the base of the Pleistocene series, but separated from that base on Long Island by deposits tentatively correlated with Professor Salisbury's Pensauken group by Veatch. The whole history is one of alternating elevation and depression above and below the present stand of the sea in relation to the land.

As is frequently repeated in the later pages of this report, the submarine Hudson channel makes it possible to admit high elevation whenever the facts over the land on the north require such an interpretation of its history.

The Hudson gorge from New York city northward is fairly distinct, as far as the vicinity of Fort Edward, where it widens out into the Fort Edward basinlike district; yet over the floor of this basin a shallow but definite rock trench is traceable northeastward along the course of Wood creek to the head of Lake Champlain.

Hudson rock terraces. The excavation of the gorge below the floor of the ancient Hudson valley has left well defined rock terraces bordering the Hudson. The terraces and the gorge have alike been somewhat modified by glacial action, glacial striae being observed very generally along the river banks through the whole length of the valley except in such places as recent rock falls from the steep bank have exposed new sections of the bed rock.

The elevation of these terraces must correspond approximately therefore with the lower levels of the ancient valley floor of the Hudson. The following figures represent the present attitude of the rock terraces between New York city and Fort Edward.

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[1] Veatch, A. C. Diversity of the Glacial Period on Long Island. Jour. Geol. 1903. 11:762–76.

ELEVATIONS OF THE HUDSON ROCK TERRACES

Kings Bridge	200
Yonkers	350
Tarrytown	140
Sing Sing	160
Croton	140
Peekskill, Verplanck and Buchanan	140
Garrison	200
Cold Spring	220
Dutchess Junction	160
Poughkeepsie	200
Albany	220
Schuylerville	300
Mouth of the Moses kill	200

The rock terraces bordering the Hudson gorge are rather uniform in elevation. The terraces are higher now on hard than on soft rocks, higher in the Archaean belt of the Highlands and southward to Yonkers and over the Palisades than elsewhere; lower on the soft Hudson shales and slates and in the region of the Triassic sandstones. The lowness of the terrace on the east bank between Peekskill and Dobbs Ferry is accounted for by the former overlap of the Triassic basal beds in this region; but these differences of level are not all accounted for by differential erosion, including glaciation and weathering, as between the hight in the Highlands and about Yonkers. The terrace hight from Sing Sing southward to Kings Bridge appears too high, and in view of the rapid falling off of the terrace level in New York city and as marked by the decline of the Palisade ridge in Hoboken and southward to its pre-Cretaceous level, indicates a local uplift, central about Yonkers.

The narrowness and local absence of the rock terrace within the Highlands is to be taken as evidence of the slower or belated cutting through the Archaean rocks of that district. The terrace is clearly shown, however, at West Point, Highlands Station and Garrisons, and appears to have extended through the Highlands as the old floor of the Hudson valley, thus indicating the existence of a water gap here at a time as remote as the epoch of

base leveling in which the ancient floor of the Hudson valley was worked out.

Davis[1] in 1891 referred the excavation of the Hudson valley to Tertiary time and the cutting of the trench in this lowland to late Tertiary or a post-Tertiary beginning.

Rock channels of the upper Hudson valley. The Hudson gorge is fairly well defined as far north as Fort Edward by the present course of the river. At that point the river falls into this rock channel from the west very much as the Mohawk falls into it at Cohoes, but the rock gorge is traceable north-northeast into the Lake Champlain valley.

The divide today between the Hudson drainage and the Champlain drainage in this gorge lies about 5 miles northeast of Fort Edward and is a scarcely perceptible watershed 147 feet above sea level. It is owing to this feature that the Champlain canal connects the two drainage basins with relative ease and few locks. [*See* the Glens Falls quadrangle for details of the topography]

The present course of the Hudson from the eastern edge of the Adirondacks to Fort Edward is evidently of postglacial origin, for the river runs over ledges at Fort Edward, at Bakers Falls, at Sandy Hill and again at Glens Falls, dropping from the 300 foot contour at the edge of the mountains to about 130 feet at Fort Edward. West of Glens Falls the river has sunk its bed in meanders into the glacial sands which form a delta made on the melting out of the ice which lay in the lowlands in this upper part of its valley. These sands thickly cover the bed rock topography. Whether the river in preglacial times flowed southward so as to join the Hudson gorge at or below Fort Edward or turning to the north just west of Glens Falls and following the valley of Halfway creek emptied into Lake Champlain is at present an open question, which can only be decided on evidence from borings which are at present wanting in this section.

It is evident that Halfway creek flows in a well defined channel but partly filled by the debris of the last ice invasion [*see* Glens Falls sheet].

Ballston channel. From near Schenectady an old rock channel trends north-northeastward by Ballston toward Saratoga. South

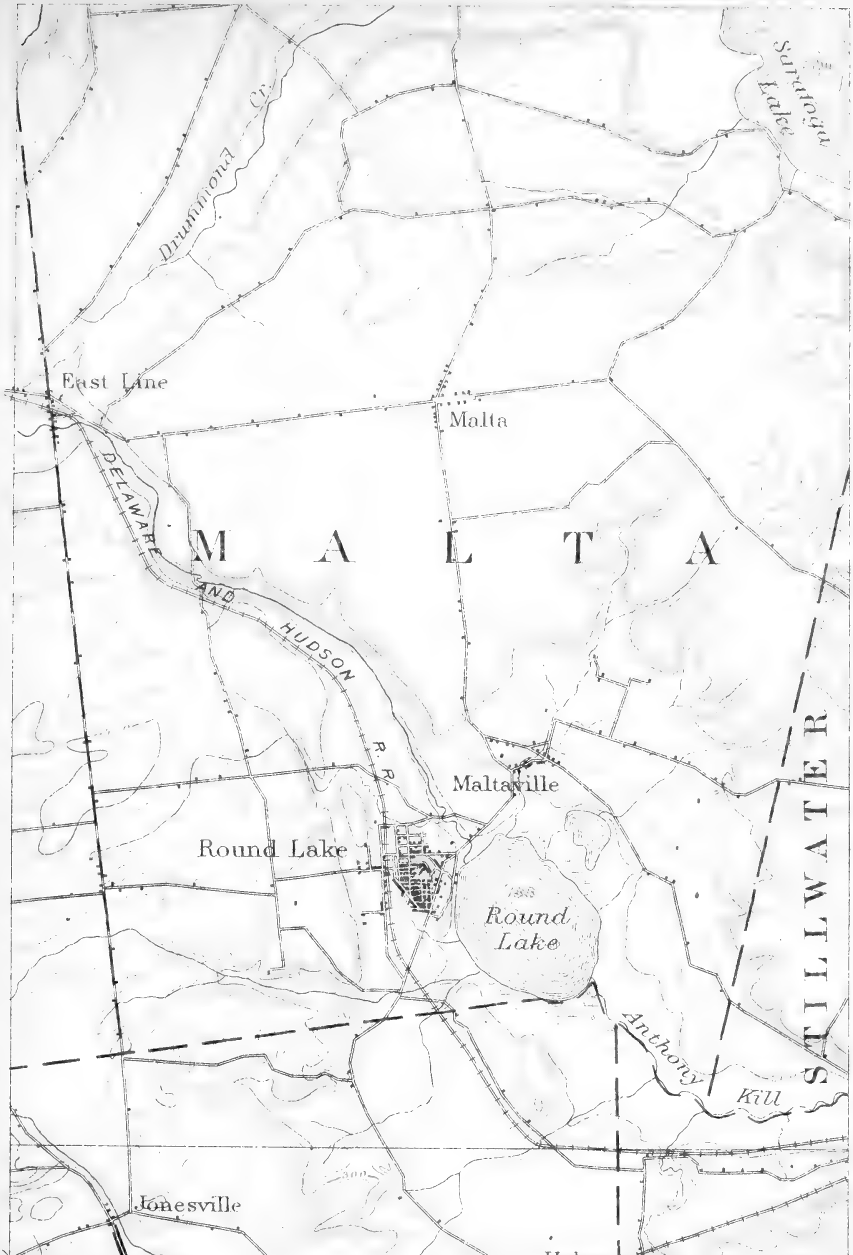
[1]Bost. Soc. Nat. Hist. Proc. 1891. 25:318–35.

of Ballston a stream escapes from this gorge by a narrow defile into the circular depression in the bottom of which lies Round lake, a body of water which in turn is drained by a narrow valley into the Hudson at Mechanicville. This system of channels antedates the last ice covering of the district, for portions of the region including the flats bordering Round lake are covered with glacial boulders. Singularly enough these depressions were not filled with the clays of the Mohawk delta stage probably because as will be shown later the ice sheet lay over the region while these clays were deposited on the east and south.

The Ballston rock channel is dependent, in part, on structure. The Hudson river slates, essentially flat on the east of this trough except for small overthrusts, are seen standing vertical within it north of Ballston lake. Erosion in Pleistocene time has excavated the channel along the vertical beds, which are evidently separated from the horizontal strata on the east wall of the valley by a fault. Ebenezer Emmons[1] recognized the existence of a fault extending southwestward from Saratoga towards Schenectady but he makes no mention of the Ballston rock channel.

Round lake channel. The large circular depression in the bottom of which lies Round lake [*see* pl.1] opens eastward through a narrow valley into the Hudson gorge at Mechanicville. Little or nothing is known concerning the real extent of the depression in the bed rocks of which this largely drift-masked cavity is a part. The Hudson river rocks rise on the west between Round lake and the Ballston channel and may be seen in the narrow defile cut by Anthony kill, a stream which now drains the Ballston channel from East Line to the divide south of Ballston lake. The plain between Round lake and Saratoga lake is at least in part a till-covered surface as about Malta. It seems probable that Round and Saratoga lakes are unfilled depressions marking the site of an old valley west of the present Hudson gorge. In the later development of the glacial lakes in the upper Hudson and Champlain valleys the various channels from Fish creek southward through the Ballston and Round lake channels probably will be found on further study to have served as temporary waterways at a time

[1]Agric. N. Y. 1846. 1:135.



THE ROUND LAKE REGION

Showing an unfilled area

Scale $\frac{1}{62500}$

1 ½ 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

when the Hudson gorge from Fort Edward south to Albany was not so deeply excavated as it now is.

Wood creek channel. The valley of Wood creek, to which reference will be repeatedly made in this report, forms at present the lowest line of communication between the upper Hudson valley and that of Lake Champlain. The divide between these two valleys lies at an elevation of about 147 feet, near Dunham basin [*see* pl.13]. It will be noted from the map that the old gorge of the Hudson appears to be continued in this direction and that the Hudson river above Fort Edward falls into this broad open channel along a new path characterized by falls and a much less width. As will be noted in a later chapter the Wood creek channel appears to have been for a time the outlet of a glacial dammed lake extending from near Dunham basin northward over the site of Lake Champlain.

PHYSIOGRAPHY OF THE CHAMPLAIN VALLEY

Lake Champlain appears to occupy an irregular depression excavated mostly in the lower Silurian and Cambrian rocks corresponding in this respect to the Hudson in its gorge from Albany southward. The present depth of this erosion feature is at least 500 feet below sea level in the deeper part of the lake. The equivalent of the rock terraces of the Hudson, or the floor of the older, wider valley in which the newer and narrow channel has been excavated, is found along the shores of Lake Champlain in a dissected rock surface as in Essex, along the Vermont shore south of Burlington, and widely developed about the northern part of the lake. This ancient valley floor is about 300 feet above the present sea level. Both this surface and the newer valley excavated in it have suffered more from glacial erosion than has the analogous topography of the lower Hudson valley. The Wisconsin ice sheet pressed into the northern portal of the Champlain valley in a strong flowage coming from the northeast rather than from the north so that the maximum erosion line must have been thrown toward the base of the Adirondacks in the position of the lake basin. No facts are at hand, however, to show how much, if any, the lake basin was deepened by ice action. Many of the streams, such as the Ausable, which now enter the lake over high level rock

benches in lateral valleys owe their present courses to glacial embarrassments. The Ausable has an old valley near Keeseville west of its present course, and the drift filling must be very deep at and above Keeseville.

The deep notches of the Winooski and the Lamoille rivers through the Green mountains, draining lowland basins on the east of this range, correspond in topographic development with the high level valley floors worked out in the Adirondacks, but this stage is apparently older than that of the immediate vicinity of the Hudson and Champlain valley floors.

GLACIAL MOVEMENT THROUGH THE HUDSON AND CHAMPLAIN VALLEYS

The observed striae throughout the Hudson and Champlain valleys, accord closely with the direction of the axis of this great depression and with the expansion and contraction of the valley walls. Throughout the entire district the direction of transportation of debris, the arrangement of the glacial deposits, the form of roches moutonnées and every feature indicative of glacial erosion points conclusively to the general southward movement of ice from the broad open northern expanse of the Champlain valley southward.

Along the New York shore of Lake Champlain there is marked tendency of the striae to turn southwestward, indicating a movement of the ice upward over the basal slopes of the Adirondacks as the ice became pressed within the narrowing southern part of the Champlain valley. At Port Henry this tendency is so marked that it may be doubted whether further detailed examination of the region back from the lake may not show the existence of local glaciers moving down the slope so as to produce the eastwest striation seen just south of the town [*see* p.156].

Through the southern arm of Lake Champlain the ice moved southwestwardly through the defiles of the mountains and out on the plain about Fort Edward. This southwestward movement is well shown at Glens Falls where striae have a course n. 63° e. Thence the movement was southward through the Hudson valley. About Albany the ice appears to have backed up in its advance against the Helderberg escarpment on the south and west. It has long been known that, in this latitude,

the ice pressed southeastwardly over the state line into Massachusetts. Pressing southward through the Hudson valley the Highlands must again have profoundly influenced the movement of the ice both in its retreat and in its advance. The ice passed through the Highland gorge leaving a characteristic glaciated topography in the smoother northern slopes of the high ridges which overlook the river and plucking out boulders from their southern slopes, thus giving the frowning cliffs which meet the eye as one ascends the river. The extension of the lowland developed over the soft Hudson slates to the southwest along the northern side of the Highlands would have afforded a passage for the ice in that direction. The ice passing through the Highlands and at the maximum of glaciation over the highest ridges, must have had a relatively rapid motion through the lower Hudson valley. The axis of this flow passed, as Salisbury has shown by detailed mapping of the striae, to the west of the Palisade border of the gorge over the Hackensack lowlands of New Jersey. On the west of this line the ice moved southwestwardly over Newark N. J., and on the east of the line southeastwardly over New York city to the moraine on Long Island.

The form of the valley and the Hudson gorge must have influenced strongly the retreat of the ice, and many of the glacial deposits, described in the following pages, demonstrate this point so clearly that, in view of the light which they throw on the several stages of the melting ice as it dwindled away from a complete covering of the eastern part of the State to long tongues of ice comparable to a valley glacier, it becomes possible to outline the history of the retreat in relation to the varying cross-section of the Hudson valley and in regard to the control which the distribution of the ice mass exerted on the character and order of arrangement of deposits made either by the ice in moving debris to its margin, or by the streams which built deposits along that margin.

THEORETIC MODE OF RETREAT OF REGIONAL GLACIER FROM A VALLEY

Enough is now known of regional glaciers such as that which spread from the region north of the St Lawrence into New England and New York to enable us to depict the general mode of retreat of the ice sheet in different districts, having deep meridi-

onal valleys on the one hand like that of the Hudson and broad uplands or sea border plains, on the other such as occur over central and southeastern Massachusetts. Here we are solely concerned with a long, well defined meridional valley.

As the ice front retreats northward there is found evidence of its having halted from time to time at certain places long enough to build moraines of dumped and shoved material on the one hand, and to allow the construction, from the outwash of sands and gravels, of deposits of these materials in the form of plains, cones and deltas more or less sharply marked on their northern or iceward aspect by evidence of deposition against or in the presence of masses of melting ice. The ice melting out back of such accumulations, either moraines on the one hand or outwash plains on

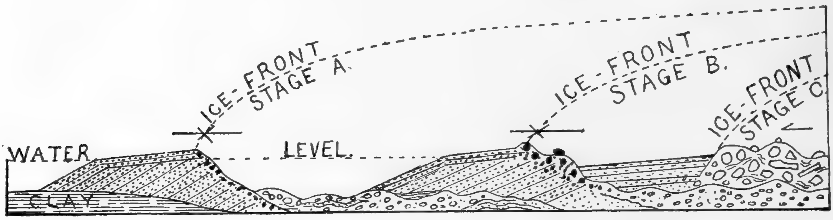


Fig. 3. Successi on of glacial deposits during retreat. Theoretic distribution of glacial deposits from north to south in New York and New England: *A*=stage in which a moraine has been formed and is confronted by an overwash plain; *B*=overwash and outwash plains; *C*=a later morainal stage with outwash sands.

the other, may have left but a veneer of till or gravel over the glaciated bed rock. At an indefinite distance to the northward other frontal accumulations will appear marking the next stage in the retreat.

In the case of these deposits the coarsest detritus of glacial origin will appear next the ice front of the time in the form of till or of coarse gravels and sand; farther away in the direction of the flowing waters finer sands will appear and still farther away the clays which remained for a time in suspension. The succession of deposits will appear as in the above diagram [fig. 3.]

If the deltas are built in standing water their outer lobate margins will indicate the approximate hight of the water plane of the time, be it sea level or lake level. If building takes place on an area from which the waters escape to the sea without ponding,

alluvial fans will form with their outer margin blending indefinitely with stream level as in the stage numbered C.

So long as the ice sheet fills the valley and covers its divides, terrace building within it is precluded. As soon as the ice has retreated it will also have thinned, and the time will come when a long tongue of ice fills the valley. Reflection of heat from the bare rock walls will cause the ice to melt most rapidly on its margins. Along these marginal depressions with rock walls on one side and ice walls on the other the drainage will escape. Temporary lakes may form in this situation whether the ice be in motion or stagnant. The situation will then appear somewhat as follows [see fig. 4].

Into these marginal troughs will be carried sands and gravels by side streams coming from the uplands now freed from ice.

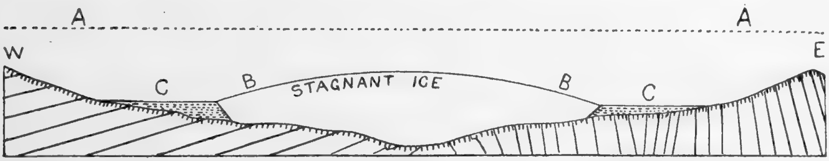


Fig. 4 Cross-section of valley with marginal glacial deposits. Theoretic condition in meridional valley back from the ice front when glacial has thinned in the form of a long tongue of ice or valley glacier: *A*=maximum development of regional glacier; *B*=surface of the ice at any given stage of thinning during retreat; *C*=site of lakes and deposits on margin of glacier.

Along these depressions will also sweep the lateral streams. The evident tendency will be to build deposits of gravel and sand in the presence of the ice as in ordinary stream beds with a slope toward sea level, but owing to melting ice with perhaps sudden changes of level causing lower and lower stages of gravel and sand building toward the mouths of the streams. When the ice melts out, these deposits will form terraces with margins reflecting more or less the form of the ice sheet against which they were constructed. The effects may be reproduced at successively lower levels marking stages in the evacuation of the valley. These stages should be correlated with frontal moraine or delta stages. Marginal remnants of the ice sheet might lie out for some time to be surrounded by gravels and sands, thus giving kettle holes and ice block holes in the contemporaneous ice-bound terraces, when the ice finally disappears.

In case the sea invaded such a valley during the ice retreat, it would control to a certain extent the deposition of washed gravels on the sides of the ice tongue but, unless the submergence were very great as compared with the depth of the valley, local embarrassments to seaward drainage would undoubtedly occur. Such embarrassments would arise where spurs entered the valley between side streams, or where the ice melted less rapidly, thus giving rise to levels of building above sea level.

Application of theory to the Hudson valley. The peculiar form of the Hudson valley, its rock benches or terraces inclosing a deep gorge, and the Highlands through which the river passes by a narrow defile with a constricted development of these benches, must have affected in a marked manner in its different sections the mode of retreat of the ice margins and consequently the distribution of the sediments laid down in the presence of the ice. First the north and south depression through the Highland section whether or not a continuous river valley as in postglacial times would have guided a strong current of ice southward and during the period of final melting would have given rise to a long tongue of ultimately stagnant ice occupying the valley north of the Highland gorge.

It is to be presumed that the barrier opposed to ice movement by the Highlands would have led in the advance, as in the retreat, to a stage when the moving ice banked up against the northwestern wall of the Highland ridges would have poured through the defile at West Point as a small valley glacier spreading out on the rock terraces below Peekskill or pushing south wholly confined within the Hudson gorge; at least in the retreat this was the case when certainly this gorge had its present general cross-section.

Wherever during the retreat the ice front crossed the river and deployed on the banks to the east and west, the streams discharging from the ice would bring down heavy loads of clay, sand and gravel, and bank them up against the ice front in the river gorge and over the neighboring rock terraces. Such deposits might originally completely fill the gorge, to be subsequently partly removed in the renewal of ordinary river drainage in the area.

When the ice had thinned so as to form a long narrow tongue filling the lower portion of the valley, covering the gorge and a considerable breadth of the rock benches on either

side, the streams from the neighboring open country would build their deltas against the ice margin in the form of terraces involving buried shreds of the ice margin, and having when the ice melted away kettles or depressions marking the sites of these buried or partially inhumed ice masses, and a relatively steep but perhaps hummocky or kamelike terrace front overlooking the river gorge and at varying distances from and elevations above the gorge. The water thus impounded against the ice margin would flow along the ice edge or finding its way through crevasses and water tunnels in the ice escape with the glacial drainage without producing marginal stream phenomena.

Finally when the ice had melted off from the rock terraces for a time a long narrow tongue would still occupy the gorge itself forcing some of the drainage over the rock benches and covering them with sheets of clay, sand and gravel. This coating of glacial materials might here and there mantle the ice in the gorge where that had been lowered by melting so that its surface lay below the level of the rock terraces. In any event when the ice finally melted out of the gorge the rock benches would be coated with terrace drift to their edges, the deposit here and there descending into the gorge as if it had once entirely filled it though this may never have been the case. Unless the evidence of ice contacts be found, it would be an extremely difficult task to determine with certainty the original extent and limits of such deposits and to discriminate them from remnants left from a reexcavation of a gorge which has once been filled by glacial sediments.

Moreover, such lateral glacial deposits will depend for their elevation on the hight of the rock terraces on which they have been spread out. From point to point they should merge into the frontal deposits of the successive stages of the retreat of the ice front. Along such frontal lines the materials would be coarsest, gradually passing to finer and finer materials toward the south or away from the ice if the drainage was in that direction. Here and there lateral tributary streams would pour in their contribution of detritus and produce local variations of texture or thickness of the sediments.

If the ice retreat by successive oscillations in which the recessional movements overbalance the forward ones, the complica-

tions in the sedimentary history will be greatly increased. The glacial clays laid down in the outer belt of deposition of one frontal stage may be eroded by the overriding action of the ice of the next and then sheeted over, partly or wholly, by deposits of till or boulders as well as by sheets of coarse gravel and sand.

Another effect producing local terraces will arise during the melting of ice from a gorge like that of the Hudson with dissected walls quite independently of sea level so long as the rock terraces rise somewhat above sea level. As soon as the ice is limited to the main gorge, the embayments in the wall, receiving drainage from the ice and such lateral streams as may pour into them from the open country, will form temporary lakes and be filled and sheeted over with sands or gravels at levels determined by the effectiveness of the ice barrier and the duration of the process of filling, as well as by the elevation of the floor of the area of deposition.

Successive stages in the cross-section of a melting glacier in a valley like that of the Hudson river. The glacier which covered eastern New York, it may be said, was pushed on to the area by the pressure of its own accumulation in the Laurentide district. Eliminating the effect of forward motion in the ice and supposing the glacier to have been stagnant over the region between the Highland canyon of the river and the Catskill mountains, it would follow that for some time during the declination in the thickness of the ice sheet the relations to the valley would be those indicated, in figure 5, in which the ice sheet not only filled the valley but covered the divides on either side.

For a long time after, when the ice had dwindled down to a tongue filling the bottom of the valley, its cross-section would have been that shown by *BB* in figure 5 and this general cross-section would have been retained till a final stage was reached, when the ice filled the gorge only leaving the top of the rock terraces free for lateral drainage.

In this final stage the cross-section would be that shown in *DD*, figure 5, in which the broad rock terraces might become the seat of lakes and lateral stream deposits. Upstream and behind constrictions in the valley where the terraces became wedged out as in the Highlands, by unconsumed spurs from the valley sides,

lakes might arise in which the deposition even of clay would become possible.

During the first stage when the entire district was ice covered, water-laid drift would be limited to subglacial stream deposits including eskers and probably some kames; during the second stage when the drainage from the top of the ice and from the valley sides could escape laterally between walls of ice and rock, deposition might take place high up on the valley sides in the form of lateral moraine terraces, lateral kame terraces and deltas built by streams coming off the ice or down the valley sides, but the iceward margins of these deposits would be subject to derangement from the further melting of the ice. In the last stage, when the ice became confined to the gorge, the rock terraces on either side

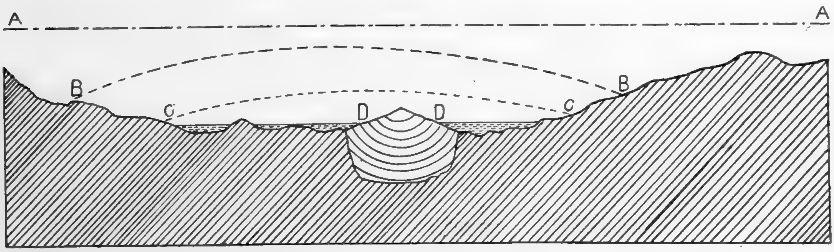


Fig. 5 Cross-section of dwindling ice sheet in middle Hudson valley at different stages in relation to the valley form. *AA*=maximum development of ice; *BB*=local ice; *CC*=ice reduced to a glacier covering old valley-floor; *DD*=ice remnant filling gorge only

would become the seat of lakes and open-air streams with a great variety of deposits. Such deposits would resemble river terrace deposits but near the edge of the gorge they would probably display coarser materials fed on to the rock terraces by the melting of the ice. Kettles and kames would occur here and there where deposition had taken place over and about the fringe of ice lapping over on the rock terrace.

The effect of any slight forward movement of the ice during the progress of melting would simply tend to maintain the ice margin longer at any one position and thus favor the greater development of the deposits at that stage, for forward movement if due to supply of ice from behind would both thicken the ice and increase the length of the glacial tongue.

The effects of the second or valley stage offer no difficulties of recognition, but in the third or gorge stage of the ice remnant it is necessary to discriminate the lateral masking terraces which

may originate in this way from terraces resulting from the reexcavation of a gorge completely filled by extraglacial clays or other materials after the ice has vacated the immediate district. Figures 6 and 7 illustrate these conditions in their simplest mode of occurrence.

In the former case coarse gravels and sand would be expected to predominate as the direct result of the outwash from the melting ice lying in the gorge but rising above the level of the terraces. Clay making would go on only in lakelike expansions above constrictions in the valley or downstream in the extraglacial field of that stage. The iceward margins of such clay deposits would pass into coarser

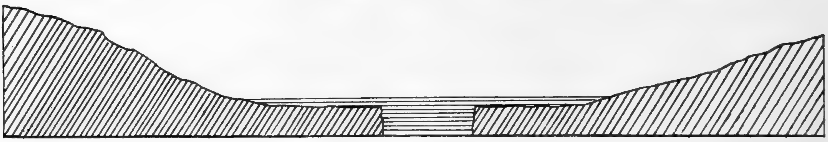


Fig. 6 Valley floor and gorge filled with clays

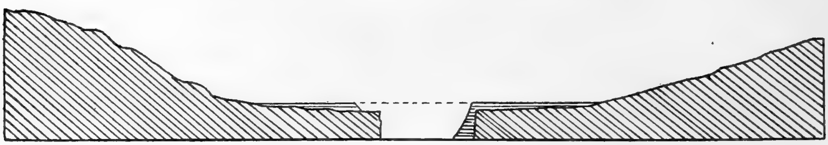


Fig. 7 Reexcavation of gorge, showing variable erosion of clays from opposite banks

detritus coming from the ice margin. Both sands and clays would fail to be deposited in the gorge except where the ice remnant receded by melting from the sides of the gorge, a condition which might locally occur before the ice shrank so much as to permit drainage altogether through the gorge. The distinguishing characteristic of such deposits would be evidence of contact with the ice sheet along the edge of the gorge, locally coarse deposits in that position, and the failure of remnants of these deposits to appear in the gorge except in alcoves and recesses or side channels not held open by the ice.

The distinguishing features of an excavated filling would be sought in the equality of hight of flood plain deposits on opposite sides of the gorge, the essential identity in the lithologic characters of contemporaneous sections on opposite sides of the gorge, and in the occurrence of remnants of the deposits in any part of the gorge protected from subsequent erosion.

Chapter 2

RETREAT OF THE WISCONSIN ICE SHEET FROM EASTERN NEW YORK

In this and the following chapters which deal with the evidences of the retreat of the ice sheet from the Hudson and Champlain valleys, the aim has been rather to determine the conditions of the drainage and water levels at the front of the ice sheet than to attempt a presentation of a full account of the successive stages of the ice retreat. Many additional facts, such as are presented here, concerning gravels and sands deposited about the ice margin in the Hudson and Champlain valleys remain to be described and located on maps.

The data concerning water levels derived from deposits made at successive stages in the retreat of a glacier must necessarily pertain to a series of water bodies whose levels may or may not have been permanent as the water extended itself into the area abandoned by the retreat of the ice front.

In relation to the very beginning of the ice retreat, there are two classes of evidence bearing on the position of sea level at the mouth of the Hudson river, one of these categories of fact lies outside the glaciated area, the other lies inside that field and forms the body of matter with which we are concerned.

Extraglacial evidence of water levels. At the time of the culmination of the late Wisconsin epoch when the ice sheet stood farthest south and at New York Narrows, the question arises whether the sea was where it now is, or whether the land stood higher or lower in relation to sea level. Of the geologic evidence outside of the glacial deposits of this epoch, there are three localities within a few miles of New York city which were examined critically with reference to this question. These localities comprise the vicinity of Cheesequake creek, on the Monmouth county shore of New Jersey, the small unglaciated area of Staten Island N. Y., and the ridge which extends through Far Rockaway on Long Island N. Y.

Terrace at mouth of Cheesequake creek, Monmouth county, N. J. Cheesequake creek occupies a valley about 2½ miles long and with an average width of 1 mile from near its mouth on the beach of Raritan bay to its head. Except for small streams entering on the northwest near its mouth and on its eastern side from the

radial drainage area of Morristown, Cheesequake creek receives no affluents adequate to account for the development of a valley extending southwestward into the mainland at this point on the coast. This abnormality is the more striking from the fact that in those parts where streams might be expected, the land slopes away from the depression and streams flow on that slope to the South river or to the Raritan itself. Everywhere about the margin of the cove steep slopes prevail without that adjustment which occurs in the drainage outside of the area, showing that the basin is more recent than the drainage furrows which surround it. In general form, in its relation to side streams and to the surrounding nonglacial topography, this cove resembles what appears to have been the original condition of those indentations of the north coast of Long Island which have been occupied and somewhat enlarged by the ice of the last advance. The creek is newer than the plain and is evidently drowned beneath the sea level by recent sinking.

Along the shore at the mouth of this cove are well defined terraces, the remnants of a plain about 30 to 40 feet above the present sea level. This plain has been dissected and partly destroyed by the erosion of the cove, and it has been cut back by the sea, so that its slope and its initial seaward margin are now indeterminate.

The upper portion of this plain on the west side of the creek consists of coarse yellow gravel lying on Cretaceous clays. On the east side the underlying deposits rise to the surface of this plain, which cuts across different beds thus showing that it is a plain of denudation. The point to be determined is whether this plain is due to marine or aerial erosion, or in other words whether it can be taken as an index of the attitude of the land in recent geologic time, and if so what was that attitude and when was it taken. The fact that there is no equivalent of this plain in the glaciated area shows that it is earlier in origin than the culmination of the Wisconsin epoch and hence makes it presumable that the land was then and has since been unsubmerged.

The topographic map exhibits a number of terraces along this coast from Perth Amboy around the Neversink Highlands to the mouth of Shrewsbury river, whose elevations vary from 40 feet downward.

Unglaciated area of Staten Island. Two very distant small tracts within the State of New York lay beyond the reach of the last ice advance; one in the extreme southwestern part of the State, the other an area about half a square mile in extent at Garretsons and Grant City on the southeastern face of the serpentine hill of Staten Island. On a sloping shelf ranging from 120 to about 250 feet above the sea lies an ancient pre-Wisconsin surface of weathered products surrounded on the northwest by the terminal moraine and on the southeast in the low grounds by the outwash gravels of the Wisconsin ice sheet. The iron crusts segregated in the weathering of the bed rock encumber a reddish soil unmixed with exotic material and topographically unaffected by any sign whatsoever of other agents than the meteoric conditions to which the areole is now exposed. The soft erodable materials form an escarpment descending from the 120 foot line to approximately the 50 foot contour line along which they disappear beneath the fresh gravel of the last ice advance. It is difficult to admit a transgression of the sea, however slight, over this surface without some trace of its action being left behind. This area appears to the writer as a monument of long continued land conditions, beginning before the Wisconsin epoch.

Far Rockaway ridge, Long Island. The outwash plain of the terminal moraine on the south side of Long Island is interrupted at Linwood by a singular ridge of gravels which extends southwestward to Far Rockaway inclosing behind it Jamaica bay. In a recent publication of the museum I recognized this deposit as being older than the terminal moraine and its outwash plain, and from my failure at the time to find granitic pebbles in the gravels referred the deposit to the pre-Pleistocene series. At about the same time Professor Salisbury[1] in a publication of the United States Geological Survey described the deposit as a shallow water formation practically contemporaneous with the outwash plain thus including it in the Wisconsin epoch and inferring from it the presence of the sea, if I understand his position correctly, at a somewhat higher level than now along the southern border of Long Island. Later I visited the ridge with Messrs Fuller and

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[1]Salisbury, R. D. New York City Folio. U. S. Geol. Sur. 1893.

Veatch of the Geological Survey and with them found feldspathic pebbles, which would in my opinion place the deposit within the Pleistocene series of Long Island. Messrs Fuller[1] and Veatch[2] now regard the deposit as an exposure of the Manhasset series, presumably pre-Wisconsin, and I see no reason at present for not accepting their conclusion. The deposit is necessarily mentioned here on account of its supposed bearing on the marine limit at the mouth of the Hudson. These recent investigations show, it seems to me, that the Far Rockaway gravels even if deposited beneath sea level long antedate the retreat of the Wisconsin ice sheet.

INTRAGLACIAL EVIDENCE OF WATER LEVELS

The following notes on particular localities by no means give a complete diagnosis of the retreatal stages of the Wisconsin ice sheet. In none of the cases have the ice margins been traced away from the floor of the Hudson valley to the higher levels of morainal accumulation and marginal drainage which undoubtedly can be traced when detailed mapping is undertaken. The account begins with the outermost moraine on western Long Island and on Staten Island.

Terminal moraine and outwash plains. The terminal moraine on western Long Island is confronted on the south by a gently sloping creased plain of gravel and sand sheeting over older glacial gravels and deposits of Cretaceous age. The surface of this plain is apparently in the state in which it was left when the ice retreated from the crest of the moraine on its northern limits. Its southern margin, now below sea level, exhibits along the shore line unmistakable signs of recent subsidence. Thus at Babylon, dredging in the drowned outer portion of one of the creases brought up abundant land vegetation from a depth of 10 feet of water. That the material was not transported and deposited was shown by the growth of roots in the peaty layer which formed a part of the mass. Similar facts have long been well known.

Port Washington and College Point deltas.[3] At Port Washington on Long Island north of the terminal moraine is a well

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[1] Fuller, M. L. Resurvey of Long Island. Science.

[2] Veatch, A. C. Diversity of the Glacial Period on Long Island. Jour. Geol. 1903. 11:762-76.

[3] *See* N. Y. State Mus. Bul. 48. 1901. p.653–59.

defined delta of sand with an ice contact slope on the north marking the position of the ice front against which the deposit was built by outflowing glacial water. The level of this deposit is 80 feet above the present sea, but in such relation to the surrounding geography that it clearly has been built in a temporary lakelet held in back of the terminal moraine over the site of Manhasset bay.

Farther east and at the lower level of about 40 feet above the sea there is a much smaller delta with a kame habit on its northern margin built as far as can be judged at a later stage in the retreat of the ice sheet. The internal structure of this deposit has shown a lower plane of water level at about 35 feet. These deposits on the northern flank of the terminal moraine have such discordant levels for stages of deposition which must be regarded as nearly though not exactly contemporaneous that it seems highly improbable that their water levels coincided with sea level at that time.

Glacial delta near Perth Amboy. East of the railroad crossing between Perth Amboy N. J. and Maurer at a point about 1000 yards south of Maurer station, a small rounded spur of sand with an elevation of about 30 feet projects eastward and slightly north on an embayment of the marsh of Arthur kill. The deposit is a spur from the moraine-covered clay beds of the terminal moraine. In the spring of 1901 this deposit was being cut away for the sand which it contained. The section displayed in April, when visited by Dr F. J. H. Merrill and myself, well defined topset beds from 3 to 4 feet thick overlying the truncated edges of foreset beds dipping about 32 degrees east with a little northing, displaying the typical structure of a delta, whose water level must have been at about the 30 foot contour line according to the reading by the map.

The outer slope of this deposit is rather more subdued than in the normal sand plain lobes of southern New England and suggests modification by standing water. From the base there is a slight projecting terrace 5 or 6 feet above tide level. The form of the whole deposit was so ill defined that without seeing the cross-section I should not have taken it for a glacial sand plain. It is evidently related to the deltas above described.

Deposits near Pelham N. Y. Hutchinson creek is a small stream entering Long Island sound at East Chester. From Pelhamville southward to East Chester the stream is bordered by terraces of glacial material, somewhat effaced by postglacial erosion. The terraces stand at an altitude of about 60 feet at Pelhamville and descend to or near sea level at a distance of 2½ miles. In the upper part the deposit is coarse gravel, with boulders intermixed along the contact with bordering outcrops of gneiss and schist. Below the 40 foot contour on the south the materials are conspicuously finer.

In the 20 foot terrace on the east side of the stream there is a frequent cross-bedding from 6 to 10 inches thick with the dip of the cross-beds to the southeast, and this invariably so, indicating continuous current movement such as that of a strong flowing stream of water. The entire section recalls that of the glacial outwash. The slope about 30 feet to the mile is rather steeper than the distribution of the materials would indicate for a stream flowing into the present sea level. If the water level was then at about 20 feet, the slope of the terrace back of and above this limit would accord with the slope of outwash plains.

Englewood sand plain. Salisbury in his work in New Jersey in 1894 described many ill defined but recognizable glacial outwash deposits made in succession in the retreat of the ice across the interval between the Palisades and the Orange trap range. One of the most notable of these accumulations is that extending from Highwood through Englewood, forming the divide between the waters flowing southward into Newark bay and those flowing northward through the Sparkill cut into the Hudson.

A line of kames extends northeast and southwest along the head of this deposit, turning northward along the east side of the Northern Railroad of New Jersey and merging into the drift at the base of the Palisade slope. The elevation of the plain at the southern margin of the narrow kame belt is about 60 feet. Thence the plain slopes southward to about 40 feet in Englewood Center, gradually descending to 20 feet in the southern part of that town. At one point on its eastern margin in the stream valley which borders the deposit, topset and foreset beds were seen in my visit, indicating a water level at about 30 feet.

The frontal margin runs out into a long spur on the western side ending at about 20 feet above the present sea level. In front of the plain is a flat of fine sands. A well sunk in April 1901 southwest of the railroad station reached rock at 67 feet. Above the rock was "hardpan," and above that about 10 feet of clay.

Van Cortlandt park plain. The parade ground at Van Cortlandt park on Tibbits brook in the northern part of New York city is a somewhat modified natural plain or terrace whose surface is about 20 feet above sea level. It is composed of glacial sand and gravel and is of either late glacial or early postglacial date. The surface of the plain now shows no trace of kettle holes, and the slope to the stream on the east and south has no decisive character except it be nearly in front of the ancient manor-house where the slope is marked by a few headstones and also along the southern end of the plain. A few coarse angular pieces of drift rock lie on the slope near the old gravestones. This fact and the manner of ending of the plain in this direction on the broad open valley of a sluggish tidal creek suggest that the plain may have been built in waters confined by a melting remnant of the glacier. It should be borne in mind, however, that direct evidence of the deposition of such gravels and sands in some part of their margin against masses of ice does not in such a situation as that of the Cortlandt park plain exclude the possibility of the water level, if such there was to control its upward growth, having been at sea level.

Certainly the sudden ending of the deposit on the south in a terrace without delta lobes and without evidence of having been brought to this form by the excavation of the drift in the valley below this point makes it probable that the valley toward the Hudson was ice filled, and thus entirely possible that the deposit was made above sea level. In short, the plain at Van Cortlandt park does not demand a higher stand of the sea than that now existing.

Tappan moraine [*see* pl. 2]. The first definite morainal accumulation in the Hudson valley north of the Narrows is encountered on the west side of the Palisades immediately north of the New Jersey boundary in the village of Tappan. At this point the Palisade trap ridge is deeply dissected on a northeast-

southwest line at Piermont, through which cut a small stream now drains the marshes back of the Palisades into the Hudson. The morainal deposits stand above this swamp in the form of two northeast and southwest ridges of mounded drift rising from 100 to over 120 feet above the sea level. They are both cut off by a small stream on the west of Tappan village.

The northern of the two ridges is nearly straight in its course, its southern slope being more uniform in direction and steeper than its northern.

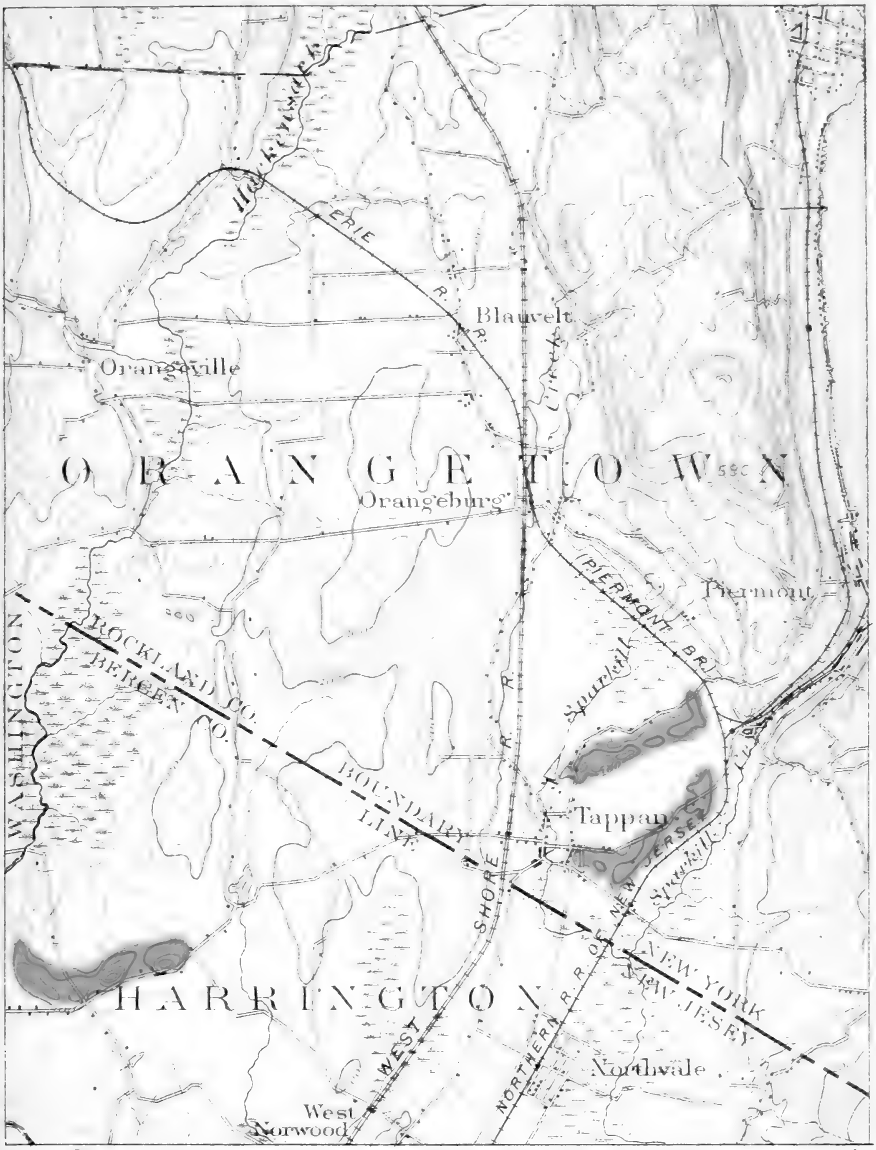
The southern ridge trends southwestward from near Sparkill railroad station for 1 mile when it turns abruptly northwestward into the village of Tappan, having thus a convex southward curvature as seen from the north though its southern front is decidedly angular.

Both of the ridges are composed largely of red gravelly drift. An excavation just south of the Sparkill railroad station showed gravels and sands with occasional small boulders, the upper part of which deposit is without stratification. The surface of both ridges is comparatively free from kettles but carries many boulders, now particularly noticeable about the houses.

A nearly smooth water-laid drift plain lying between 60 and 80 feet above sea level separates the ridges, and drains to the westward; but more significant is a small frontal apron of washed gravel and sand which extends beneath the swamp at the southwestern end of the outer or southern ridge, sloping from about 60 feet at the edge of the moraine to 40 feet where it disappears southward beneath the recent swamp accumulation, fixing the upper limit of the water body or lake into which it was built as lower than 40 feet at the time of this stage, but giving no closer index of sea level.

The position of these frontal moraines, just north of the Piermont gap, plainly indicates that at this time the gap was free from ice, presumably allowing the escape of the drainage as now into the Hudson gorge; nor does the Hudson river appear to have flowed through this gap since the ice last disappeared from its valley. Just east of the Sparkill station glacial striae on the trap rock read n. 24° w. a direction about at right angles to the moraine showing that, though the striae may have been made

PART OF THE TARRYTOWN QUADRANGLE



THE TAPPAN RETREATAL MORAINES.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Frontal moraines.

before the moraines, when the ice ran to the south, the direction of ice motion had scarcely changed at this locality during the retreat from the terminal moraine.

West of Tappan in New Jersey other frontal deposits similar in form to the morainal ridges at this place occur in the form of a crescent open on the north, indicating the position of the ice front at this stage in that direction.

The extension of the ice front east of the Hudson at this stage is not clearly shown by any facts now at hand.

The moraines at Tappan N. Y. and in Harrington N. J. appear by their alinement to be synchronous deposits. The water-laid drift confronting the Tappan deposits rises to 60 feet above sea level, but the plains confronting the Harrington deposit appear to rise to 100 feet. It is evident that these slopes of washed drift were not controlled by one and the same water level. Sloping plains and fans of drift are built up along certain ice fronts and along the flanks of gullied mountains, independently of water levels, to quite different altitudes above the stream beds at their base. It is therefore legitimate to suppose that these deposits may also have developed without regard to sea level or lake level, so that the sea level of the time may have been at or below the level of the lowest of these diluvial fans.

Nyack terraces preglacial (pre-Wisconsin). There are two well marked terraces in the vicinity of Nyack on the west bank of the Hudson, but these are so many benches formed by the Triassic sandstones outcropping beneath the Palisade trap sheet. They are everywhere except in the southern part of Nyack covered by glacial till. The lowest of these terraces is about 80 feet above sea level. The red sandstones crop out in a low bluff on the water's edge south of the village. The upper terrace is strongly marked between 180 and 200 feet and corresponds closely to the rock terrace of the Hudson at many points. Another less extensive terrace occurs south of Hook mountain between 280 and 300 feet.

On these terraces the drift is largely reddish till derived from the red sandstone and shale. For about 50 feet above sea level the surface drift is grayish and clayey, as if the ice had smeared earlier glacial clays over the rock benches.

The phenomena shown at Nyack, so far as my observations go, afford no indication of sea level since the retreat of the ice sheet different from that now existing, though this evidence is wholly negative in regard to a recent rise of the water level.

Tarrytown delta. At Tarrytown, Pocantico brook (Gory brook on the United States Geological Survey map) has cut deeply through a deposit of sand forming its ancient delta on the margin of the Hudson gorge. At Tarrytown the eastern wall of the Hudson gorge changes its course from a few degrees east of north to nearly north, and at the same time the rocky wall advances slightly to the westward. In this angle of the bank below the brim of the ancient rock terrace on the northern edge of the town lies the deposit named.

The surface of the deposit is about 60 feet above sea level, rising in a small mound to above 80 feet. On the north it is bounded by steep slopes, in part cut back by the stream which flows at its base and in part an original depression evidently marking the presence of ice while the sands were being deposited.

Deposits south of Croton point. The ice which covered the Hudson valley south of the Hudson Highlands assumed a lobate margin at the time of its halt along the line of the terminal moraine. The axis of most rapid motion in this lobe lay on the west side of the Palisade trap ridge in the Hackensack lowland of New Jersey. East of this line the ice moved southward and eastward across the lower Hudson; west of the line the ice moved to the southwest at angles somewhat greater than the southwest course of the lower portion of the Hudson itself. During the retreat of the ice from the moraine toward the southern edge of the Highlands it is to be presumed that the same general bottom movements of the ice would have been maintained till the ice thinning over the Highlands continued to push through the Highland gorge alone and thus became restricted to a small glacier occupying the Hudson gorge.

The margin of this small glacier it is believed is found in the frontal deposits at Croton point and in the vicinity of Haverstraw; but the deposits south of this stage in the retreat pertain to the broader development of the ice sheet which had not as yet lost its marginal continuity with the ice sheet extending eastward

over New England and westward over the Highlands of New Jersey. In the retreat from the terminal moraine however it is to be expected that the lobate form of the ice in the lower Hudson would be retained, and since the axis of the lobe lay in the lowlands west of the Palisade ridge the east margin of the lobe in its retreat would first uncover the east bank of the Hudson from New York city northward and then the western bank of that river. This relatively earlier opening of the east bank of the river would permit of the drainage from the open country in Westchester county pouring in against the ice margin so as to make deposits partly built against the ice either within the open parts of the gorge or within the dissected rock terrace itself. On the contrary, on the west bank no such deposits would occur, largely because of the lack of an open land slope toward the Hudson.

In this lower section of the Hudson the stratified glacial deposits are restricted to the east bank in situations suggesting in their form and distribution their constraint by the ice margin. The slight mounding of the deposits at the head or ice contact of the outwash plain at Englewood and again near Tappan village show that the ice at these stages of retreat was slightly quickened and advanced on its frontal outwash deposits, movements which would have extended to the eastern margin, accounting for some distribution there of till over stratified deposits and a slight shoving of stratified beds into disturbed positions.

This inequality of the distribution of stratified deposits is shown elsewhere as on the banks of the Taunton river near Fall River, Mass., where stratified drift, locally a kame terrace, flanks the south side of that southwesterly trending arm of the sea while till without signs of water modification covers the other bank quite down to sea level.

The rule in such situations is that when the ice is retreating with its front nearly or quite parallel to a river valley the bank which is first uncovered by the ice will receive outwash from the ice and inwash from the confronting land while the opposite bank may be left strewn with the ill assorted or unstratified boulder-bearing drift dropped by the ablation of the ice. On the open side of the valley, terraces and kame terraces may thus be formed at levels independent of the sea but above its level.

All the terraces and plains in the lower Hudson south of Croton point, those at Port Washington, College Point, Maurer, Tarrytown and Van Cortlandt park, accord with this mode of retreat, and the slight but recognizable evidence which they bear of the presence of the ice along this eastern bank of the Hudson makes it reasonable to grant that the levels which they exhibit are those of local bodies of water held in position by the ice and hence subject to capricious changes.

Croton point stage. The strongest development of glacial deposits, such as are peculiar to the front of a retreating glacier, in the Hudson valley north of the great terminal moraine in Brooklyn and south of the Highlands, occurs at a point in the valley where there is again an important change in the geologic structure of the region. At Haverstraw, the thick sill of intrusive basalt which forms the palisades of the western bank of the river curves inland and westward, presenting its steep front to the north. At the same time the Hudson valley eroded in the Triassic basal beds widens out to the westward, and the gorge occupied by the existing river from Ossining (Sing Sing) northward bends around in deference to the geologic structure of its western bank. On the east bank there debouches just south of Croton point the Croton river, a curvilinear stream whose northward curvature may be compared with that of the trap ridge which touches the opposite shore at Haverstraw. We shall first consider the glacial conditions as they are found at Haverstraw, and then proceed to the interpretation of the deposits at Croton point and in its vicinity.

Haverstraw glacial deposits. The glacial deposits at Haverstraw from the base of High Tor northward along the shore and to Stony Point, for a mile or more inland, are rather complex, consisting of the more striking brick clays, glacial sands, gravels, and also till in the form of a frontal moraine. The extensive opening of the clay beds affords numerous opportunities for examining their structure and relations.

Frontal moraine. Once the ice front in its retreat lay north of the curved ridge of trap above referred to, any tendency to move southward would be met by the obstruction which this westward curving ridge offers, and as the ice, on the whole retreating,

had its times of slight advance, it is but natural to expect slight frontal deposits built against the northern slope of the Palisade ridge where its course turned so as to lie athwart the path of ice motion. Such deposits actually occur.

The morainal deposits of this stage are well shown at the Haverstraw station on the West Shore Railroad. The material is a reddish till in a thick deposit lying approximately between 100 and 200 feet above the sea from the vicinity of the railroad station to and beyond the limits of the Tarrytown atlas sheet. The conditions of the ice front at this time are indicated in the accompanying cross-section drawn across the front between High and Little Tor [fig. 8]. South of High Tor this morainal coating fails to appear as a flanking deposit on the iceward side of the trap ridge. As will be described in some detail presently,

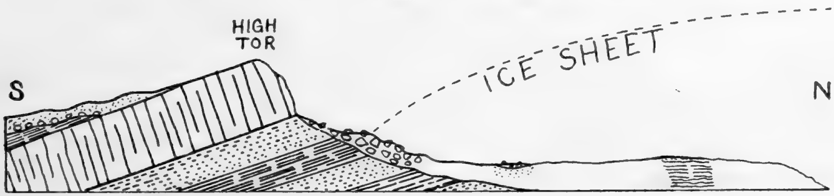


Fig. 8 Diagrammatic cross-section showing relation of ice sheet to frontal moraine at Haverstraw: below cliff, the moraine; to the right, clays, sands and gravels

morainal deposits reappear in the northern part of Croton point and it is therefore reasonable to suppose that the ice front left the west bank of the river in the vicinity of Short or Long Clove and crossed the Hudson gorge to the east bank, curving or projecting southward in mid-channel.

While the ice lay in the Hudson gorge south of Short and Long Clove, these two passes across the Palisade ridge would have afforded an outlet for the lateral drainage flowing between the ice on one side and the trap wall on the other. The long straight course of the Hackensack from the Cloves down to West Nyack is so well developed as to suggest that the stream may have been enlarged in the glacial period by water pouring through these passes, which lie at about 200 and 220 feet above the sea.

About $\frac{1}{5}$ of a mile south of the West Shore bridge over Minisceongo creek and east of the railroad there was a sand knoll exposed in 1900 in which stratified sands from 40 to 60

feet above the sea contained glacial boulders as if they had been dropped in from floating ice. Small lenses of gravel without pebbles of the trap or red sandstone betrayed their more northern origin than the area of Newark rocks. The upper layers of this section were much crumpled as if by overriding ice. The sands as a whole were yellowish and clayey. At one point a deposit of till lay in a shallow depression or channel in these sands.

The surface of this sand knob is clearly an erosion form. The crumpling of the upper layers, and the occurrence of patches of till show that it antedates the last local ice advance; yet the boulders dropped within it point to water at least 60 feet above the present sea level, during the deposit of the sand. But this water had nothing to do with the last glacial retreat.

The precise relations of these sands to the moraine at the base of the trap sheet is not shown by sections, but the evidence of ice action over the sands and the failure of sand deposits over the moraine, points evidently to the greater antiquity of the stratified deposits north of the moraine.

Cedar pond brook and its deposits. The clays in Haverstraw and North Haverstraw rise to about 50 feet above sea level though they are largely eroded away so that from place to place they rise to various hights below this level. In the northern part of Haverstraw between the 60 and 80 foot contours, the clays are overlain by about 10 feet of coarse gravels. South of the east and west road a pit in 1900 showed erosion of the clays before the deposition of the gravels.

Going farther north toward the valley of Cedar pond brook boulders appear in fences over the clays and also over a sand plain with foreset beds inclining to the southeast, showing the action of a stream pushing its delta out in this direction at a level as high as 60 or 80 feet above the present sea level.

Cedar pond brook has in recent times sunk its bed deeply and widely into its ancient delta the largest remnant of which forms the flat projecting point of land on which stands the village of North Haverstraw, at an elevation of about 100 feet above the sea.

This deposit evidently formerly extended farther south across what is now the path of the stream, thus uniting the coarser gravels and sands over the clays perhaps as far south as Benson's

Corner in a sheet of outwashed detritus, the position of which on the clays shows its more recent deposition. The precise age of these gravels and sands can be fixed in terms of the glacial retreat with precision, for the northern margin of the coarse detritus in the 100 foot plain at North Haverstraw shows clearly, by the ice contact slope of the terrace, that the deposits were along that line banked up against the edge of the glacier which still lay in the Hudson gorge. The age of the terraced remnants of the old delta is therefore fixed as nearly the same as that of the moraine at Haverstraw and earlier than all the various frontal deposits yet farther up the river in the line of retreat.

While the Cedar pond brook deposits are thus considered here as connected with the Croton point stage of the retreat it has to be recognized that the ice edge on the west side of the river had retreated from the moraine at Haverstraw station to the northern edge of the delta at North Haverstraw, a distance of 2 miles.

The clays underlying the Haverstraw gravels and sands are normal glacial deposits, evidently made in more or less open water the surface of which must have been at least 50 feet above the present sea level, but as the clays are overlain by the delta deposits made at the time the ice sheet pressed against the gravel bank at the North Haverstraw station, they can not be associated with deposits made at a later time when the river was freed of ice as far north as Albany. The precise age of the clays at Haverstraw is necessarily somewhat in doubt. North of the old delta with its ice contact at the North Haverstraw railroad station clays lie in the low grounds quite up to the south side of Stony Point. The clays rise up in the small hillock south of that point and evidently have there been much eroded. South of them rises the bluff of gravels in the North Haverstraw delta on which clays have not been deposited. Everything in this locality points to the conclusion that the clays are here older than the Cedar pond brook delta and that the ice sheet rested on these clays when the delta began to build. It is not so clear that the upper clays south of the Cedar pond brook were also in existence before the ice sheet retreated to the north shore of Cedar pond brook.

As previously shown on page 80 clays will begin to deposit along an ice front somewhat in advance of the sands and gravels

which the streams lay down along the ice margin and in contact with it. As the gravels and sands are dragged along and deposited further out, they will begin to cover the earlier deposited clays, and thus we shall have as the progressive steps in the deposition of a harmonic series of sediments the appearance in the lower and outer portion of the delta of an earlier set of clay beds and a later set of beds of gravel and sand. While the beds seen in any one vertical section are truly older at the bottom and newer at the top, the difference in age in this case is very slight.

Since the clays south of Cedar pond brook rise higher than those north of the head of the delta at North Haverstraw it is probable that the upper part represents the earlier clay deposits of this stage of delta building instead of some far earlier deposits like those seen near Stony Point. These clays will be found again in Croton point and further discussion of their origin may be deferred till that deposit has been described.

Croton point. On the east side of the Hudson, Croton point presents one of the most striking features of glacial origin in the course of the river from its source to the sea. There are larger and thicker deposits of drift but none which intrude themselves so forcibly on the plain map of the State. Croton point is again a complex of glacial deposits. The outer insular portion of this cape is partly of ice-laid morainal origin. All about the shores of Tellers point northward to the northern unnamed point the beach is lined with large glacial boulders. Dark boulders of a basic igneous rock are common and boulders of a red conglomerate undoubtedly from the Triassic strata underlying the Palisade range occur being derived probably from the basal strata of that formation in the bed of the river. On the western side of the north point the deposit of till with boulders and gravels rises high above the water level, showing that the ice front lay against this edge of the deposit, and as pointed out on page 99 that the ice front of the Haverstraw moraine crossed the river at this point, resting on the rocky shore of the eastern bank at Croton Landing where again thick deposits of till occur. The approximate position of the ice front at this stage is shown in the annexed sketch map [fig. 9].

In front of this ice edge Croton river appears to have entered into the Hudson much as it does now except at a higher level and to have deposited gravels near shore and sands farther out. At least some of these gravels and sands are preserved in the upper part of the Croton point deposit. The only question which arises is whether some of the material may not have been laid down by streams coming off from or out of the ice at this stage; but the occurrence of these plateaus of gravel and sand along

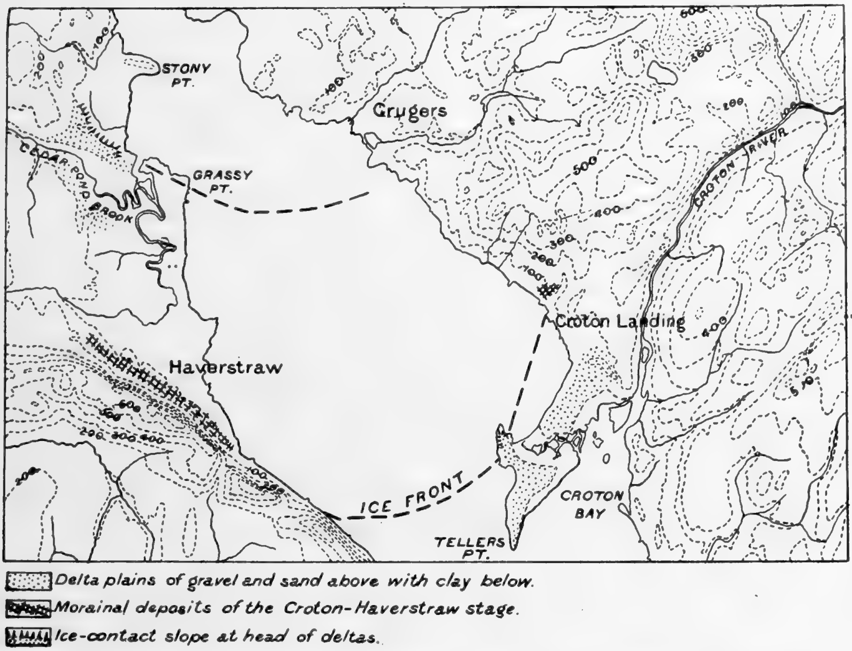


Fig. 9 Sketch map of the Croton-Haverstraw stage of ice retreat, with the later North Haverstraw stage

the ice margin at the points where streams now enter the Hudson both here and at the mouth of Cedar pond brook appears to be conclusive evidence that much of the work was done by lateral streams.

Again at Croton point as at Haverstraw the sand and gravel overlie a thick deposit of stratified blue glacial clays, which are well exposed in the pits along the north shore of the point.

Near the railroad on the north shore of Croton point about 20 feet above the beach, coarse glacial gravels with pebbles from

1 to 2 inches in diameter overlie the clays giving place above to glacial sands. At the northern point, there is reason to believe that the till is banked up against the clays if it does not overtop them. Probable evidence of the action of the ice sheet is found in the highly crumpled condition of many layers of clay; but this crumpling and contortion may have taken place as the result of the creeping of the clays when the overlying sands and gravels became thickly deposited on them. It is a characteristic of the outer clays in deltas.[1]

At the northern margin of the North Haverstraw dissected delta terrace and again at the northern extremity of Croton point there are slopes composed of coarse deposits coming directly from the ice sheet itself. These have been preserved as they were laid down, without erosion on the one hand or a covering of newer clays or silts on the other. They have suffered little from erosion because streams have run elsewhere doing their work most efficiently on the clayey deposits remote from the loose structured, gravelly beds near the ice contact. That these slopes have not been covered by newer deposits must be explained as in general due to their not lying in a basin of deposition. Either streams have not been directed toward them or if they have been submerged such submergence was very short indeed and the waters free from transported sediment. Indeed there has been no deposition above present sea level in this region since the ice retreated from the successive stages.

Cedar pond brook in cutting down through the North Haverstraw deposit has left a subordinate terrace at about 60 feet above the sea. This is a narrow terrace traversed by the road which leads southward from the village to the brook. The remnant of the old delta on the south side of the stream rises to 60 feet or over. The occurrence of a terrace at this hight made in the down cutting of the stream is suggestive of a water level at about 60 feet. The deposit at Tarrytown was built up to 60 feet above sea level. The full significance of these clues to a water level higher than that of the sea at present it is hoped to bring out in the discussion closing this report.

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[1]Russell, I. C. Lakes of North America. 1895. p.50. Also in U. S. Geol. Sur. Monogr. XI. 1885. Ries, H. N. Y. State Mus. Bul. 12. 1895. p.108, 118–19.

The Croton point deposits like the North Haverstraw delta rise to about 100 feet above the sea level where they join the rock wall of the Hudson gorge. At Tellers point the gravels and sands fall off in hight to about 25 feet above the sea. Nowhere on this southern margin do there appear signs of glacial delta lobes. On the contrary there are marks of erosion, either that by the Croton river or by the action of the waves of Tappan sea.

The wide and deep cut across the point is clearly due to erosion following the deposition of the uppermost sands and is an essential part of the history of the changes in water level and the run of streams following the disappearance of the ice from the north side of this morainal stage. The outline of the cut, concave toward the northeast, describes the path which the present Croton river would in all probability take, were the Hudson flowing north instead of south as it now does. If the Croton cut this channel the process of doing so must have been at the beginning, by coursing over the deposit then more extensive to the southward and filling in the area between Croton point and the land known as Croton bay, the opening of which has given a more direct path southward into the Tappan Sea.

Against this view it must be said that the boulder deposits at Tellers point indicating the presence of the ice along the northern edge of the delta indicate also the possibility that streams poured out on that side from the ice and during the decaying stage of the ice front when a stream became free from its load, it may well have cut this channel quite down to the present level and that independently of the presence or action of the Croton river. The presence of creases across the surfaces of sand plains and deltas laid down along the ice margin is one of the striking features of many districts where the deposits were built partly above permanent water level.

Clays at Crugers. In the vicinity of Crugers a few clay pits have been opened in glacial brick clays closely resembling in all respects those on the opposite side of the river at Haverstraw. The clays have an eroded surface, rising to various levels up to nearly 100 feet. The deposits wrap about outcrops and occur in the hollows between the older rock topography of the side of the valley. Like those at Haverstraw the clays appear to have been deposited in the roughened and broken down rock terrace of the

Hudson gorge. At various places near Crugers glacial boulders repose on the clays and frequently in positions where it is impossible to suppose that they have slidden down from the slopes which overlook the clay deposits. This distribution of boulders is quite in accord with the evidence found on the west side of the river which points to the overriding of certain clays in this part of the Hudson valley by the ice at least in those stages of its retreat which are marked by moraines and frontal washed deposits in the vicinity of Haverstraw and Croton point. It is quite possible that each one of these frontal moraines and attendant outwashed deposits marked a slight advance of the ice remnant following a retreat somewhat farther up the river, and the mere overrunning of clays in this manner by the ice itself and the sheeting over them of gravels and sands contemporaneous with the retreating ice as a whole does not of itself demand that these clays be placed anterior to this last ice epoch. But the difference in the geologic position of these clays and those which still form broad plains about Albany and as far down the river as Kingston is sufficient to demonstrate that the clays in the Hudson valley south of the Highlands belong to an earlier stage in the melting of the great glacier than those from Kingston to Albany. In other words, the clays in the lower Hudson were laid down before the final disappearance of the glacier from this part of the valley; those south of the Mohawk from Albany down to Kingston are later than the disappearance of the ice from the region which they occupy.

There is thus no continuous deposit of glacial clays in the Hudson valley precisely equivalent in age to the marine beds of the Champlain area on the north.

Terraces about Peekskill bay. Well defined terraces of glacial gravels and sands occur in the vicinity of Peekskill bay at the southern edge of the Highlands; at Tomkins Cove and Jones Point on the west shore, and in Peekskill and Peekskill creek on the east shore. These deposits will now be briefly described in the order named.

Terrace at Tomkins Cove. The topographic map shows a narrow terrace developed on the side of the valley at Tomkins Cove. This terrace is delimited by the 120 and 140 foot contour lines and agrees very closely in level with the preglacial or inter-

glacial rock terrace of the Hudson river. No detailed study of it has yet been made in this survey.

Terrace at Jones Point. On the southern side of Dunderberg mountain at Jones Point or Caldwell there occurs a well defined terrace of sand and gravel of glacial origin, the original outlines of which have now been nearly destroyed in the course of excavation of sand and gravel for masons' supplies. This terrace extends along the mountain wall for about half a mile, being widest on the south where the mountain recedes from the river. On the north near Jones Point, the terrace springs out from the mountain side at an elevation of about 100 feet as a rather coarse cobbly gravel deposit and declines southward to about 60 feet of altitude. On the south it is separated from the mountain rock wall by a narrow gully which must either have been kept open during the period of deposition or have been excavated since by running water.

The slopes of the deposit are now altogether destroyed except for a small length of frontage near the northern end, but this portion of the bank is not very well defined—it may or may not have been filled in against a mass of ice lying in the river in the manner of terraces contemporaneous with glacial tongues filling a fiord or gorge. Its structure is more definitely shown.

The southern broad part of the deposit gave the following partial section in one pit from the top down:

	Feet
Fine loam with gravel........................	4
Gravel, egg sized..........................	2
Sand	15
Gravel, very coarse.......................	30+
Sand ....exposed	4

The face of a large opening at the southern end of the terrace in July 1900 showed the following instructive section [fig. 10], from which the mode of development of the terrace may be compared to that of the glacial deltas described on page 80.

The structure of the Jones Point terrace so far as revealed is that of a gravel bar building southward by the carriage of gravels over the surface of an embankment which must have begun to form where the terrace is tied on to the mountain side

at or near its present northern end. These gravels coming to repose on the terminal slope under water formed successive inclined stratified additions to the deposit in this direction. The base of the deposit toward the southern end is sand and fine silt or rock-flour almost clayey in consistency. This finer material represents that which was washed off to the bottom at the foot of the growing embankment this being pushed out into the open water in that direction. These materials formed horizontal beds in front of the growing deltalike bar and were successively encroached on by the foot of each layer of inclined gravel and sand deposited on the growing slope of the bar. In this way origi-

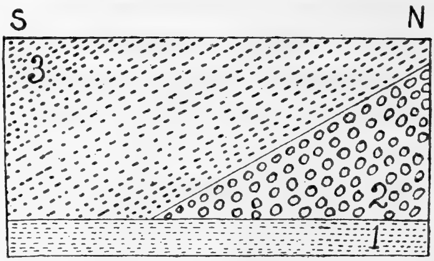


Fig 10. Section at southern end of Jones Point terrace in July 1900, showing at base horizontal beds of (1) sand, and rock-flour, overlain by southward inclined beds (dip 30°), of (2) coarse gravel with cobbles up to 6 inches, and (3) fine gravel up to 3 inches.

nated the unconformity at the base of the inclined beds. There was no erosion of the horizontal beds for they were in the deeper water with strong currents moving only near the surface.

The occurrence of coarse cobbles ranging up to 6 inches in diameter in these foreset beds nearly half a mile from the northern end of the embankment is evidence of strong currents running to the southward and on the concave shore of the present Hudson river where under existing conditions or with a higher water level it is difficult to conceive of a current of the river working at the level of this deposit being so directed as to produce the observed result. There appear to be but two possibilities concerning the circumstances of the formation of this terrace: either it was built by a strong southward flowing shore current during a time when the water level in this part of the valley stood about 100 feet higher than now or it was constructed in a glacial side channel at a time when the glacier filled the gorge in the Highlands and protruded southward as glaciers

now do in the fiords of Norway and West Greenland. The destruction of the slope of the terrace facing the river has removed the evidence which a former contact with an ice sheet or glacier would have left on the river margin of the deposit.

Terrace in Peekskill. The Hudson river winding through the Highlands approaches the southern edge of this broad northeast and southwest group of high ridges on a southeast course. No sooner is the river out of the mountains than its course bends sharply at first to the southwest then more nearly south. At the point where it escapes from the Highlands, Peekskill brook descending from the northeast finds its way into the main stream, making a small cove about a mile in length and $\frac{1}{3}$ mile wide deeply sunk into the old rock terrace. Between the city of Peekskill on the south and this creek or cove on the north stands a hill of rock rising to a little less than 400 feet. From the landing in Peekskill one may go around the southern and eastern sides of this hill into Peekskill brook valley by passing over a divide at about 170 feet. From the east a small brook now coursing through Peekskill falls into the Hudson at the southern base of this hill. On the southern slope immediately overlooking the river front at the southern end of a lofty ledge of bare rock which forms the western face of the hill is a glacial terrace with a delta structure. Well defined foreset beds below dip toward the river, and topset beds above incline very gently in the same direction. The surface of this deposit is at about 100 feet above the sea level. Its existence at this point indicates a stream carrying gravel and sand into the Hudson gorge along the south face of the hill. The deposit probably originally extended southward across the depression by which the little brook finds its way through the lower part of Peekskill, for on the south side of this valley there is a somewhat sloping terrace now at the same level occupied by residences.

There is no evidence clearly bearing on the relations of this deposit to the last remnant of ice in the Hudson river, for its river edge has been destroyed; but it is evidently a deposit made during this early stage of the ice retreat.

Peekskill creek terraces. In the valley of Peekskill creek, several deposits practically at the same level between 100 and 120 feet in elevation occur on the north and south banks of the cove,

and similar narrow terraces are not wanting farther from the main stream on Peekskill and Sprout brooks at gradually increasing hights above sea level. Those on the north side of the cove are best developed; and of these that forming the state camp is the broadest of all. I am not able to say how much it has been artificially graded. The slope of this terrace with its kamelike projections is quite unlike that of normal river-cut terraces on the one hand and lobate delta fronts on the other; the deposit appears to have been built in the presence of ice partially filling Peekskill creek. The same remark applies to the narrow terrace at the mouth of Annsville creek near the head of the same cove.

Roa Hook is an outlying rudely conical hill of glacial materials rising to the same level as the terraces in its vicinity. It has been opened for gravel and sand. On its top is a fine yellowish loam, from 3 to 5 feet thick; below this a dark coarse gravel bed, 10 to 15 feet thick, in which one large erratic was exposed in 1900; below which sands occur in the form of foreset beds dipping southeast, making a section about 30 feet thick. Near the railroad track sands occur dipping southeast at an angle of 15°. The gravels are locally cemented by carbonate of lime.

The dark shaly pebbles in these gravels are derived from the paleozoic rocks north of the Highlands in the Hudson valley. This northern source of the materials and the dip of the sand beds to the southeast show the direction of building of the deposit to have been downstream. The isolation of this deposit is hardly to be explained by the erosion of a once larger and more extended mass of glacial gravels and sands uniting all the terraces about Peekskill creek in a single deposit. The contours of the slopes or bluffs of these terraces as well as the untouched slopes of the Roa Hook mass preclude that idea; and the postulate of masses of ice partly filling the channel at this point and shrinking away from the rock walls here and there and so permitting the building up of deltas and terraces by lateral streams to a nearly common level meets all the requirements as regards the irregularity in outline and disposition of the various deposits.

A notable feature in the deposits of the vicinity of Peekskill is the complete absence of the superficial stratified glacial clays. Dr Ries has described clays rising about 4 feet above high tide level beneath the gravel and sand of the 20 foot terrace south of

Peekskill. These clays are probably an extension of the eroded ancient clays seen at Crugers.

Low level terraces. Again in this vicinity there are to be seen small areas of sandy plains stretching between rock outcrops in the dissected margin of the river gorge. One of these plains is well developed about the east shore of Lents cove, from a mile to a mile and a half south of Peekskill, with a surface about 20 feet above the sea. Another small deposit at about this level connects Roa Hook with the remnant of a rock terrace on the northwest of it. There is required much more evidence as to the nature of the original margins of these deposits on the river side before it can be asserted that they were or were not deposited in the presence of ice remaining in the gorge. They are evidently later than the high level terraces which overlook them.

Terraces about West Point and Cold Spring [*see* pl. 3, West Point quadrangle]. The topographic features of the Hudson at Peekskill are partly duplicated between 8 and 9 miles upstream within the Highlands in the vicinity of West Point. In this bend of the river, West Point with its terrace, takes the place of Jones Point, and Cold Spring on the delta of Foundry brook that of Peekskill. The ancient rock terrace of the Hudson partly masked by glacial deposits both at West Point and Cold Spring somewhat complicates the problem and gives the glacial deposits the appearance of a greater development than they really possess. It is interesting to note that Constitution island, a rocky mass in the middle of the gorge, is practically free of glacial deposits, for reasons which it is believed will appear when the bordering terraces have been discussed.

The West Point glacial terrace rises from 160 to 180 feet above the sea. The original character of the deposit is best shown north of the West Shore Railroad tunnel from the site of the cemetery to the weak morainal deposits at the base of Crow's Nest mountain. The upper deposits in this portion of the terrace are coarse cobbles becoming coarser and the deposit really bouldery near the base of the mountain named with a kettle moraine topography of weak relief. The railroad cuts north of the tunnel expose gravels quite to the river level showing that the deposit here is a true glacial terrace and not merely a coating of the ancient rock terrace as is the case near the parade

ground. There is here indubitable evidence of the deposition of the terrace in the presence of a tongue of ice lying in the Hudson gorge as Gilbert some years ago suggested.[1]

On the opposite side of the river below Cold Spring, a terrace of glacial gravels forms a counterpart to the terrace at the parade ground. It also, rests on and covers over the ancient rock bench at this point. Traces of the gravel of this stage exist in Cold Spring on the north bank of Foundry brook near the mills.

Gravelly water-laid drift also mantles the rock terrace both north and south of Highland Falls, and flattish deposits of the same character are not wanting on the rock terrace above Garrisons on the east bank of the river.

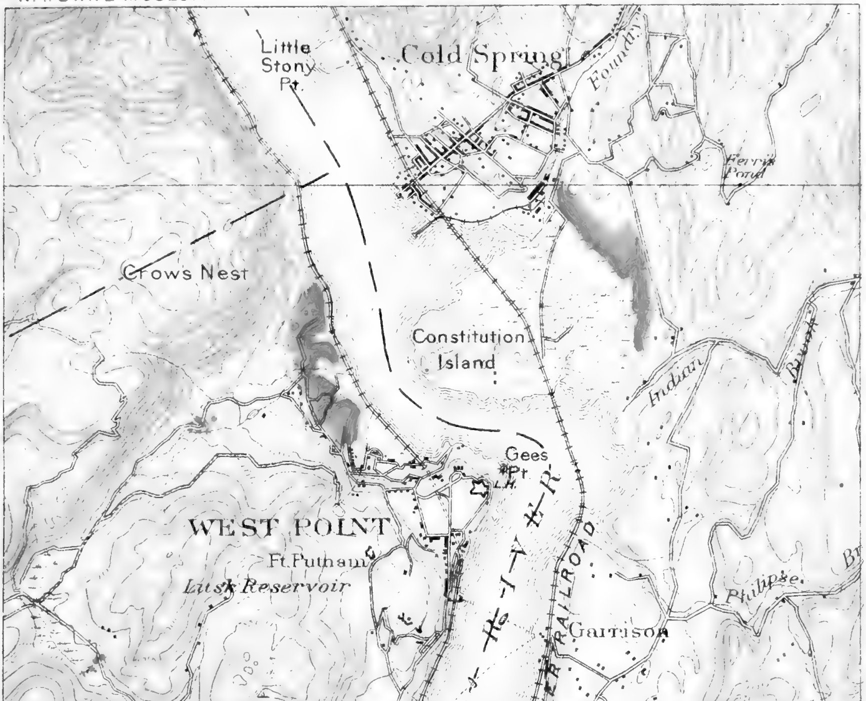
The West Point terrace is but the last and lowest of a series of deposits marking the dwindling away of the ice tongue which filled and pressed through the Highland canyon. Ascending the road passing from the soldiers quarters at West Point westward along the base of Crow's Nest mountain, one arrives within a distance of ½ mile at a small frontal moraine at an elevation of 400 feet. This deposit, mostly flat topped, is mounded on the east and though no section is shown it is probably composed in part of outwashed gravel and shoved or dumped materials coming from the ice sheet when the ice still rose to this hight in the valley.

Going westward to a junction with the Highland Falls road, then ½ mile southeast from the junction, this road traverses a distinct moraine forming a spur on the northern side of the valley. The deposit is convex downstream and is probably due to a lobelet of the ice pushed through this valley to this point prior to the halt at the 400 foot contour above West Point. These details are mentioned as showing the evidence of successive stages in the melting of the ice in the valley.

So far as the terraces at the West Point stage are concerned, their close approximation in level with the hight of the old rock terrace, the filling of spaces in the river bend upstream from the projection of the old rock terrace, and the thin veneer of the wash of this stage over the old rock terraces on both sides of the river suggest that the rock terrace controlled the hight of

[1]Cited by Dr F. J. H. Merrill, in Am. Jour. Sci. 1896. 41:461.

PART OF THE WEST POINT QUADRANGLE



DEPOSITS AT WEST POINT AND COLD SPRING.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Glacial terraces. Frontal moraine.

the terrace building by gravel-bearing streams. This evidence is stronger when it is noted that both rock terraces and glacial terraces are at this point in the river somewhat higher than at Peekskill. The elevation of the glacial terraces at Peekskill is from 100 to 120 feet; in the vicinity of West Point it is from 160 to 180 feet. Unless there has been a differential postglacial uplift of the axis of the Highlands, this difference of level of terraces at points about 9 miles apart, appears too great to be explained by the normal tilting of the continent on the supposition that the deposits were originally made at the same water level. If made, however, in ice-confined waters, their difference of level is expectable.

In the view of the terraces at West Point and Cold Spring having been laid down marginal to ice filling the channel in the

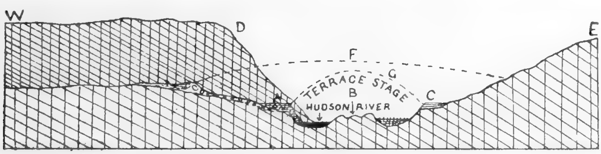


Fig. 11 Cross-section of the Hudson valley at the West Point stage. A, West Point terrace near cemetery; B, Constitution island; C, terrace south of Cold Spring; D, Crow's Nest mountain; F, ice at stage of the 400 foot moraine; G, ice at West Point terrace stage

manner of glaciers in the fiords of Norway, the lack of drift on Constitution island above referred to is at once explained, since it must have been at the time covered with ice, the cross-section of the gorge then being that shown in the annexed figure.

At Cold Spring on the south, facing Foundry cove, is a narrow terrace, rising about 40 feet above sea level.

Partial summary of preceding chapters. The front of the ice sheet retreating northward from the terminal moraine and up the Hudson valley halted temporarily at Tappan. The extension of the ice east and west of this locality is as yet imperfectly known. It certainly must have formed a broad sheet, rising on the north, over Little and High Tor, and filling the canyon of the Hudson in the Highlands if it did not also cover these last named elevations. Northward, the broad valley of the Hudson was still wrapped in the glacial sheet.

At Haverstraw and Croton, evidence exists of a temporary halt of the ice front, at a time when it had a rather marked convex

front as if spreading out on the lowland at the southern entrance to the Highland canyon. It is reasonable to suppose that at this stage the ice pressing against the northern slope of the Highlands and having thinned too much to flow over these ridges forced a long tongue through the Highlands comparable to the ice streams which are pressed out from the inland ice of Greenland to the west coast. With this stage some of the higher terraces and morainal deposits in the Highlands may be associated. Later the ice dwindled away melting at surface and also on its sides thus permitting the deposition of gravels and sands about its margins and over the rock terraces which at this stage bordered the dead ice in the gorge. With the melting out of this ice, the glacial occupation of the Lower Hudson was closed.

An earlier chapter in the glacial occupation of the lower Hudson valley is recorded in the terminal moraine and possibly also in the clays at Haverstraw which are covered unconformably by later sands and gravels. If the view be correct that the terminal moraine at the Narrows is the so called "inner" or Cape Cod moraine and that the "outer" or Nantucket moraine is to be found overrun by ice and suffused in the region immediately north of the Narrows it is probable that in the lower Hudson valley as on the east in Massachusetts the ice advanced some distance in taking up its position along both of these ice fronts. Considering these frontal moraines as respectively culminating the earlier and the later Wisconsin epoch, in the interval between the two episodes of southernmost prolongation of the ice front there would be opportunity for the deposition of some of the older clays which are found as far north as Haverstraw. On the other hand it must be recognized that the advance of an ice sheet causes it to overrun all deposits which have been laid down in front of it in its own time. It does not, therefore, from the evidence at hand, appear possible to conclude definitely whether the Haverstraw clays pertain to the latest Wisconsin or to an earlier epoch. That no clays are found in the lower Hudson overlying the deposits contemporaneous with the ice fronts in the Hudson valley, makes it evident at once that in this field none of the geographic conditions have prevailed which produced the widespread clays of the upper Hudson valley and the Lake Champlain district.

Chapter 3

GLACIAL DEPOSITS OF THE MIDDLE HUDSON VALLEY

North of the Highlands the glacial features of the Hudson take on a somewhat different aspect from those seen on the south. At Newburg and Fishkill glacial clays come to the river front in the form of terraces capped by sand and gravel, but gradually give way upstream to coarser and coarser stratified deposits, till at New Hamburg on the east bank glacial gravels appear like those near Peekskill. Thence northward to near Kingston point the glacial deposits bordering the river below the 200 foot contour are mainly ill defined deposits of gravelly till or rude kames such as are laid down where large masses of ice have melted out. The molding sands of this district are perhaps of a different origin. From Kingston northward to Albany and Troy there comes in a remarkable series of clay deposits which everywhere show by their surface being free of later drift and by their sharp incision by postglacial streams that they are distinctly later than the occupation of the valley by the glacier or its remnants and that they are, in fact, the most recent of the series of deposits which are to be associated with the disappearance of the ice. It remains to set forth what has been learned concerning the retreat of the ice sheet from the Hudson valley between the Highlands and the Mohawk north of Albany.

Cornwall terrace. On the west bank of the Hudson at the northern portal of the Highland canyon is the heavy deposit of gravel which constitutes the Cornwall terrace. The materials are very well shown in the cut bluff at the railroad station near the river. The materials all show signs of strong water action but not without the presence of ice. In the road up the hill from the railroad station a boulder 6 feet long was exposed at the time of my visit. The top of the terrace slopes toward the river and is covered with coarse drift. It is difficult to arrive at any satisfactory conclusion concerning the level of standing water at this stage from the remnant of the terrace. The surface as it exists may have been shaped above the level of the water in the Hudson gorge. The altitude of 170 feet is attained by the flat surface somewhat back from the brink of the bluff. On the

whole the deposit bears the closest analogy to the high terrace at West Point at the base of Crow's Nest mountain and occurs just where the waters ponded in the Walkill valley would escape along the ice border at the most favorable stage into the Hudson gorge. The much lower level of terraces on the north at Roseton and New Hamburg compels the belief that all the terraces in the Hudson gorge were deposited along the margin of a local protrusion of the glacier and thus lie above the level which standing water in the open gorge would have assumed at this time.

Northward near the mouth of the Moodna kill where the terrace still has an elevation of 160 feet there is a deposit of gravel and sand overlying stratified clays. The interesting terraces in this part of the kill are described on page 199.

Newburg terrace. The city of Newburg on the west bank of the Hudson is built on a splendid terrace whose structure and consequently its glacial history are somewhat complex.

The terrace is most perfect on the northern bank of Quassaic creek where its elevation is about 150 feet. The front facing the river appears to have been eroded by the natural action of the river, though it is now largely artificial by reason of railway excavation and buildings which have been arranged along it.

Setting out from Washington's headquarters, the geologist proceeding southward traverses a depression leading to the river, beyond which he surmounts the best preserved portion of the terrace, which in an east and west section shows the profile given in the figure on p.117. In this section, the terrace presents the form of a glacial plain, deeply cut away on the outward or river side, and bounded on the west by topographic features which are distinctly due to the deposition of the materials in the presence of ice in the valley of Quassaic creek. The head or iceward margin of the plain is slightly mounded as if by the pressure of the ice, and the slope into the valley on the west is cast in the form of kames and mounds. In fact the country on the west and northwest as viewed from the terrace presents a field of kames drained by the Quassaic quite as distinctly contemporaneous with the ice sheet as those which have been described in the valleys of the Chenango and other streams.[1]

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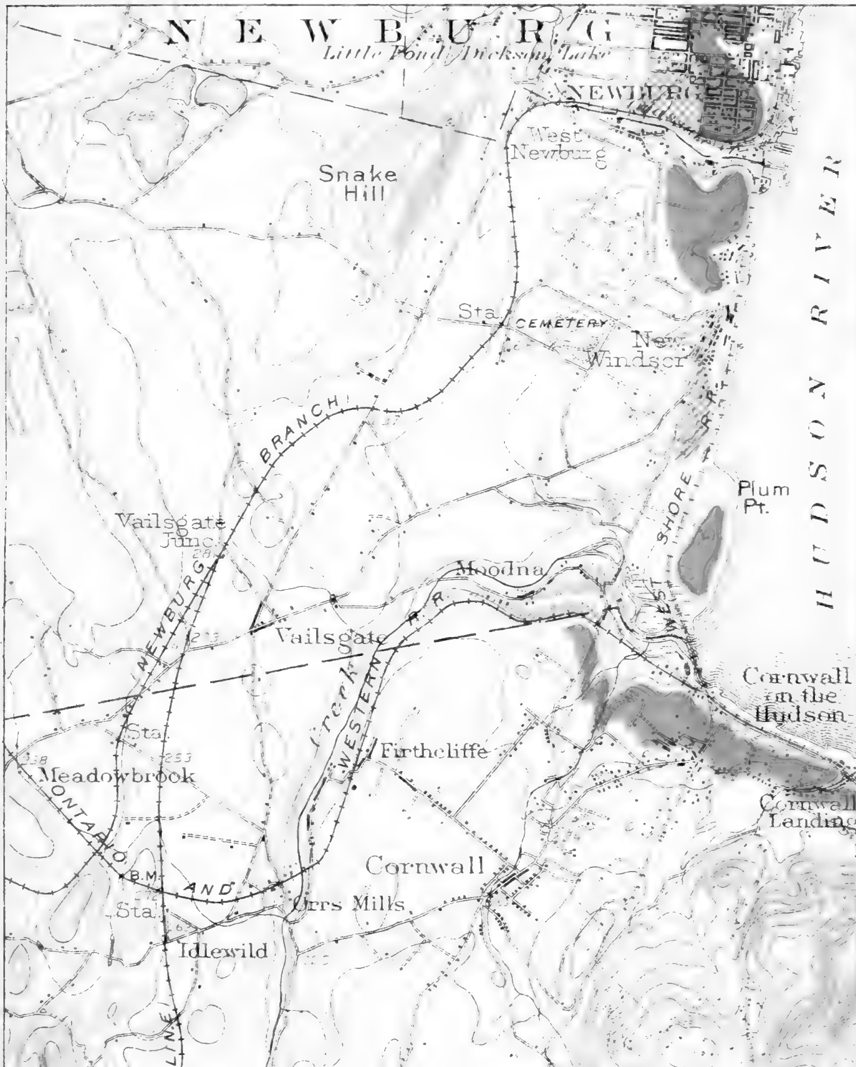
[1]Brigham, A. P. Glacial Flood Deposits in Chenango Valley. Geol. Soc. Am. Bul. 1897. 8:17–30.

PART OF THE NEWBURG QUADRANGLE



TERRACES BETWEEN NEWBURG AND CORNWALL

Scale $\frac{1}{62500}$

1 ½ 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

High level terrace deposits.	**Ice-contact deposits.**	**100-foot Terrace.**	**60-foot Terrace.**

The kame or ice contact slope of the terrace is strewn with angular stones up to 6 inches in diameter. A block of limestone lies in the morainal belt near the railroad, also ice-scratched pebbles and boulders up to 2 feet in diameter occur near the Bay View terrace.

The structure of the terrace shows that it is composed in part of clays and in part of sands and gravels. South of Washington's Headquarters Museum the clays appear to rise not higher than 30 feet above the river. Other points reveal a yellowish oxidized clay top in the plain with gravels in foreset beds beneath.

On the south side of Quassaic creek well defined foreset beds of gravel and sand form the principal part of the section down to

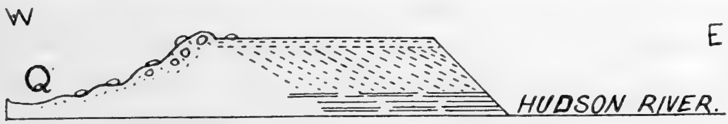


Fig. 12 Terrace at Newburg N. Y. Q, valley of Quassaic creek

the level of the West Shore Railroad tracks. These foreset beds dip eastward into the river gorge, showing that the terrace was built outward in that direction by the flow of water from the ice front lying back of the terrace [*see* fig. 12].

Another partial section on the north side of Quassaic creek, showed the following details.

LOCAL SECTION IN NEWBURG TERRACE

	Feet
Gravel, at surface	1
Sand	1
Clay, stratified	8
Sand, clayey	1.5
Gravel, fine shaly river pebbles	2
Clay above river ... about	60

These clays near the railroad track dip gently east and appear to be locally eroded. This erosion is further evidenced by the manner in which they are replaced by gravels and sands with foreset beds south of Quassaic creek. The interstratification of sands and clays in the above partial section is instructive as showing that clay making went on evidently at this stage in close

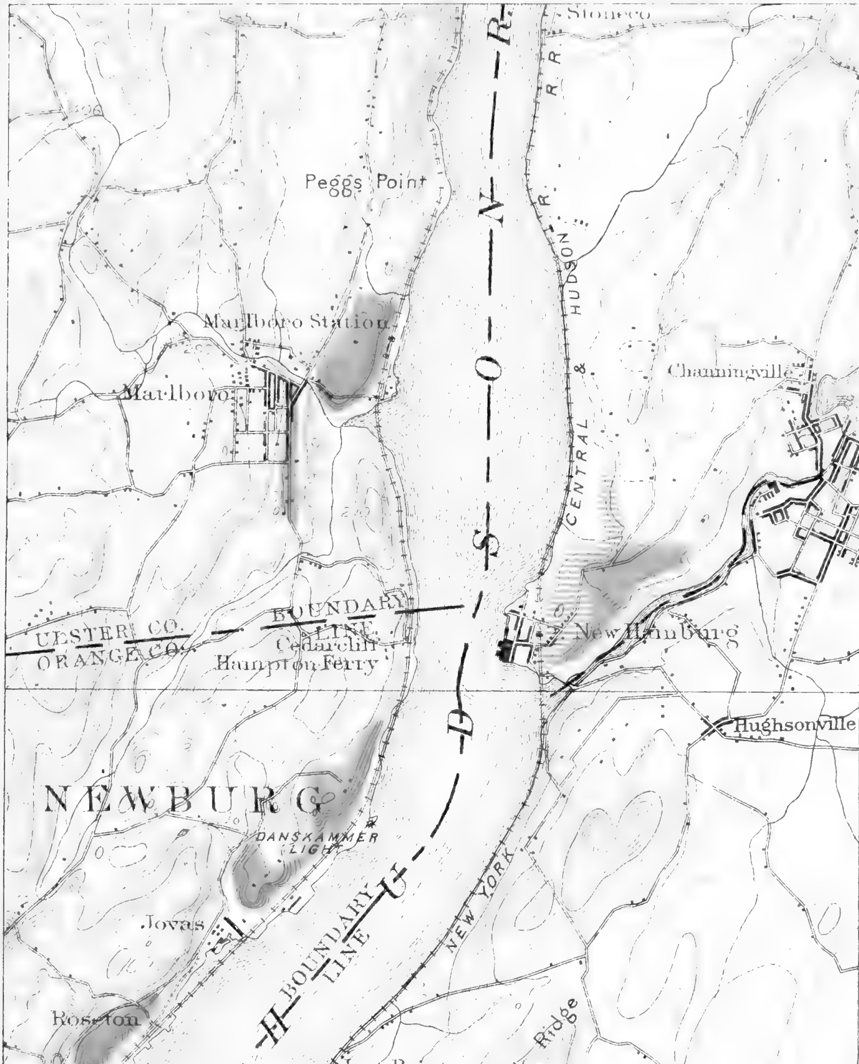
proximity to the ice front. This is a particularly important conclusion in its bearing on the clays shown on the opposite side of the river at Fishkill Landing.

The clays at Fishkill and Dutchess Junction border on the river and are apparently free from overlying gravels and sands; but higher up at 140 to 160 feet are sandy terraces apparently referable to the Newburg stage. The details of glacial structure here require further study in the light of better sections than those exposed in the season of 1900. Enough is known however to show that after the ice front had withdrawn to the north side of the Highlands, it lay along the western side of the river at the back of the Newburg terrace while deposits of gravel, sand and clay were making in the Hudson gorge in front of it.

The southern end of the ice at this stage lay near West Newburg. Marginal kames occur between Newburg and Dickson lake. At the base of Snake hill there are morainal mounds curving eastward. At Windsor station one appears to be outside of the frontal moraine. An old overflow channel or crease is well shown $\frac{1}{4}$ mile southeast from the railroad station west of New Windsor. It runs through the southwestern part of a cemetery at an elevation of 140 feet. The channel is from 300 to 400 feet wide, cut in outwash sands which rise in the southern part of the cemetery to the hight of 160 feet, showing that while the ice still remained in this field the level of standing water in the neighboring river was much below that of the 160 foot terrace. Terraces made in the presence of ice are invariably above the level of standing water in the extraglacial region. From the facts at New Hamburg described below it would seem as if the water in the open Hudson gorge was at this stage not much above 100 feet higher than it now is.

North of Newburg the surface facing the river on that side has an eroded appearance, blending with the glaciated region of the western side of the valley. It suggests to the eye the occupation of this part of the valley by the ice while the Newburg terrace was forming; in other words, the ice front here approached and crossed the river. That it crossed the river somewhere between this locality and New Hamburg is shown by the decisive evidence as to the ice front at the latter place.

PART OF THE POUGHKEEPSIE QUADRANGLE



TERRACES ABOUT NEW HAMBURG.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Terraces. **Ice-contact.**

Roseton terrace. This terrace is composed of coarse gravels dipping south in a cross-bedded structure. There are signs also of inthrusting of drift from ice movement [*see* pl. 5].

Danskammer terrace. The surface of the Danskammer terrace shows some erosion. It is capped with sand. The lower part of the terrace is blue clay. The elevation is about 90 feet. The strong contrast in the physical features of the Roseton and Danskammer terraces is rather typical of the abrupt horizontal changes met with in successive deposits seen within the gorge. The Roseton terrace can not be attributed to a river pouring into an estuary after the disappearance of the ice. It appears to have formed between the west wall of the river gorge and ice still lying in the district. The southern end of the Danskammer terrace immediately north of the Roseton deposit and at the same level points to more open conditions, and presumably is to be correlated with the outwash from the ice at the New Hamburg stage of the ice front [*see* pl. 5].

New Hamburg glacial deposits [*see* pl. 5]. From Newburg the gorge of the Hudson trends n. n. e. for 6 miles to New Hamburg on the east bank. Between these two points a few well defined terraces extremely localized occur as at Roseton and near Danskammer light on the west bank with surfaces between 80 and 100 feet above sea level. At Carthage Landing, a 20 foot terrace has a marked development.

At New Hamburg, Wappinger creek falls into the Hudson finding its way thereto through a considerable development of glacial gravels and sands which are well exposed in terraces about the pond at Wappinger falls and in the banks of the stream between that point and the Hudson river. At the village of New Hamburg these glacial gravels take on the form of a delta terrace deeply dissected by the Wappinger creek, and have a sharply marked ice contact slope on the western and northwestern margin of the deposit. The carriage road leading from the village northeastward to the top of the terrace has this ice contact slope on the right hand till the road surmounts the 100 foot contour line; thence the terrace is traceable along the river edge on the left hand, showing clearly that the ice front was at this point on the east side of the river probably crossing

to the west just above the mouth of Wappinger creek, and extending to the west of Newburg as above indicated.

It is worthy of remark here that the United States Coast Survey soundings of the bottom of the Hudson show a well marked ridge crossing the Hudson from the north side of Sherman's dock about 1 mile north of the steamboat landing at Newburg in a northeasterly direction to the east shore. Over this ridge the

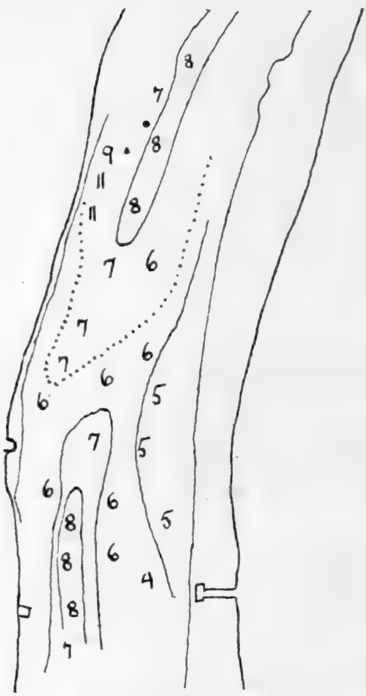
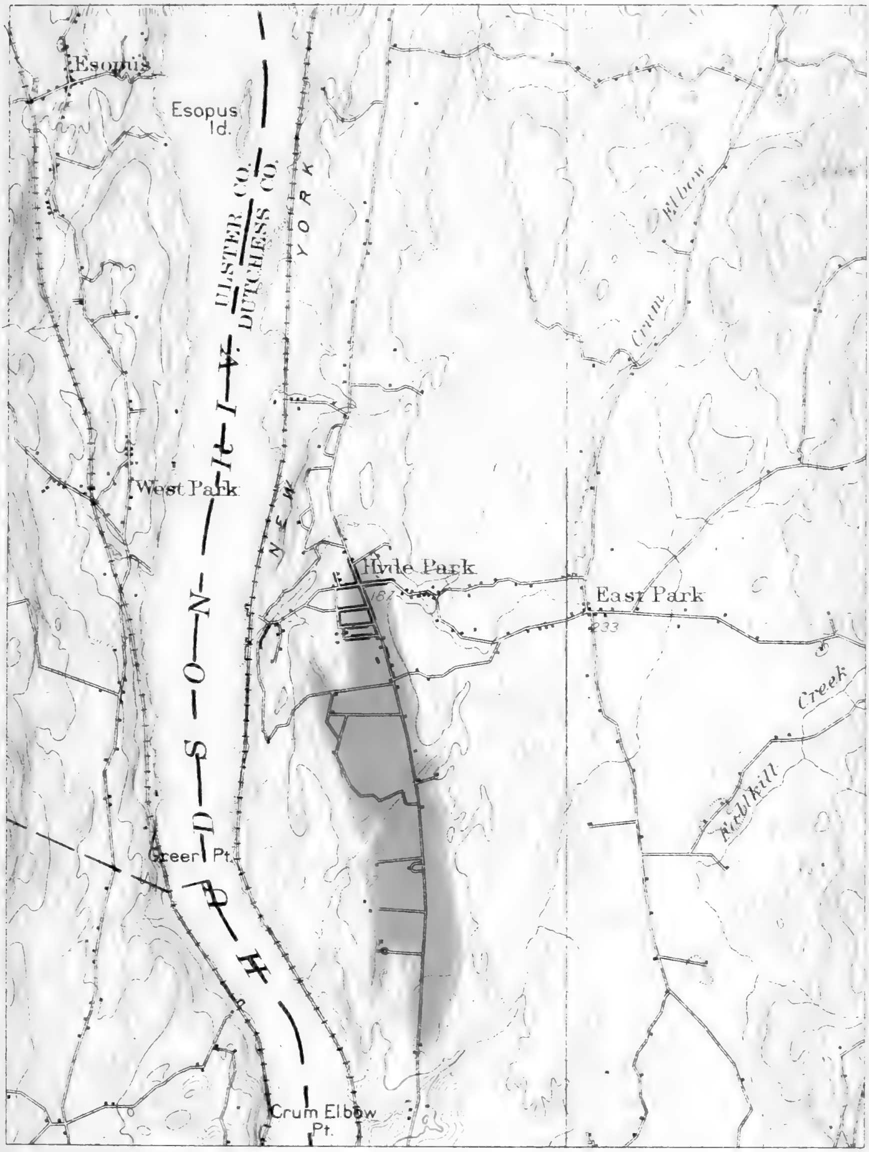


Fig. 13 Sketch map of the bed of the Hudson near Newburg N. Y., showing bar crossing the bottom of the Hudson. Figures indicate depth of water in fathoms. Constructed from United States Coast Survey chart no. 371

depth of water is 6 fathoms. North and south of this bar the channel falls off to depths of $7\frac{1}{2}$ on the north and 8 fathoms on the south and these depths are maintained for several miles up and down the river. There is no reason for supposing that this bar is a normal feature of the development of the river, and it is explicable apparently on one of two hypotheses, either that it is due to a reef of rock less eroded than the rocks north and south by glacial action in the channel or that it is a deposit made

PART OF THE RHINEBECK QUADRANGLE



THE LATERAL GLACIAL TERRACE AT HYDE PARK

Scale $\frac{1}{62500}$

1 ½ 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Hyde Park terrace.

along the ice front at the time it crossed the river. The general form of the river bottom in this vicinity is shown in the sketch map, figure 13, in which contour lines have been introduced from the soundings given by the coast survey.

From this point northward, it seems best to trace out the ice front thus indicated on the east bank of the Hudson since it presents a series of glacial deposits essentially contemporaneous, after doing which the features of the Hudson gorge may be resumed from the same point of departure.

Ice edge of the Newburg stage north and east of New Hamburg. The reconnaissance made of the Hudson valley has sufficed to trace the eastern border of the ice mass which lay in the valley north and west of the Highlands nearly to Troy, though it is probable that the facts relied on for evidence on the north pertain to somewhat earlier and later positions of the ice than that shown at New Hamburg.

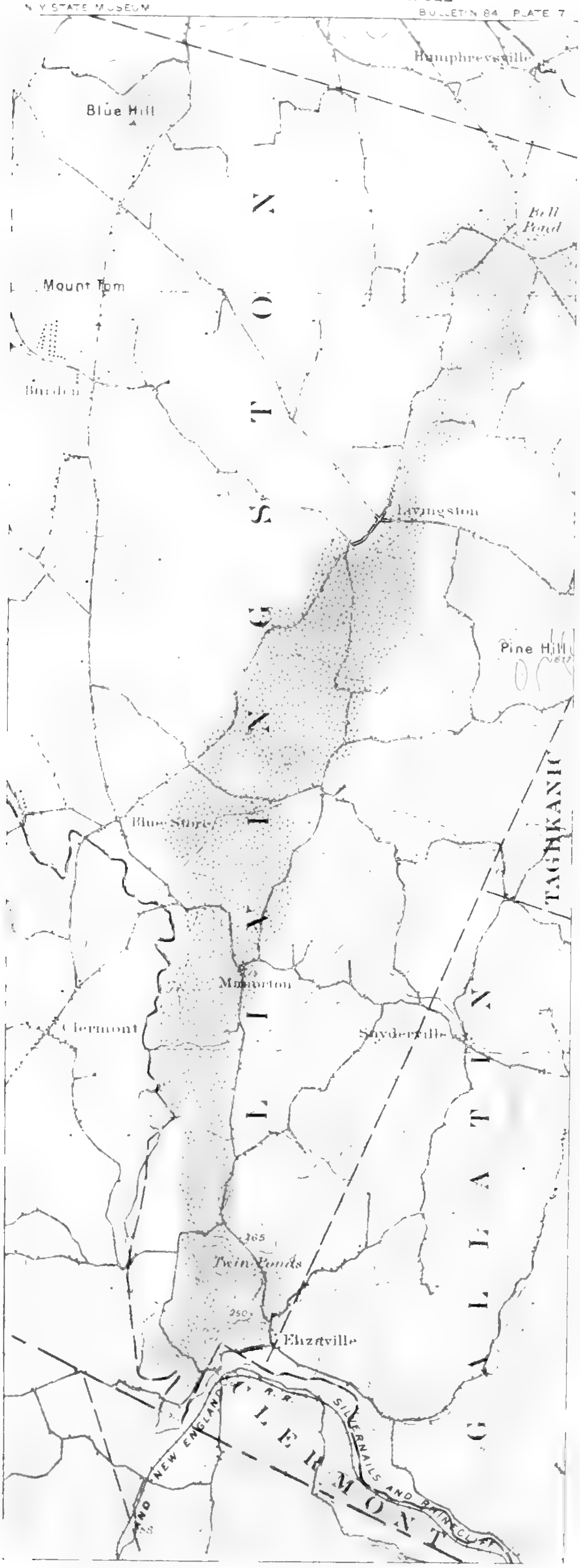
Lateral kame terraces. Between New Hamburg and Poughkeepsie [*see* pl. 6] there are terraces with kame kettles showing the site of remnant blocks of ice, and having steep ice contact slopes facing the Hudson river, the assemblage of structural and topographic features indicating that the ice overlay at this stage the eastern bank of the Hudson for distances varying from ½ a mile to about a mile as far north at least as Staatsburg. The kettle plains of this stage are well developed along Fallkill creek north of Poughkeepsie. Further traces of the ice border are found in the southeast corner of Red Hook township 1 mile northwest of Rock City at an elevation of about 320 feet. Further north in the southern corner of Livingston township the topographic map shows clearly the existence of another deposit along this line of ice front at an elevation of from 280 to 300 feet in the course of Roeliff Jansen kill. Going still further north, and at an increasing distance from the river, these kettle plains take on their most distinct and continuous development [*see* pl. 7] from near Bluestore to and beyond Livingston. A typical view of the belt may be had near the railway station at Elizaville. The ice contact slope has been locally cut back by the stream at this point. The terrace lies at a distance of from 5 to 6 miles east of the river, with its base ap-

proximately at the 200 foot contour line. The Roeliff Jansen kill appears to have discharged against the ice edge and contributed to the building of this remarkable deposit. The terrace is highest where the river now intersects it and declines in level northward. At Cokerville 2 miles south of the kill there is a fragment of the terrace which lies still higher. The question of the attitude of the surface of these deposits in relation to contemporaneous water levels and the precise attitude of the land at this stage has not been as yet investigated. Presumably the drainage along the margin of the ice at this time was southward.

According to the topography of the Kinderhook quadrangle by Mr C. C. Bassett, the Livingston lateral glacial deposits with kame kettles appear to be continued across this district at a slightly increasing distance away from the river as they are traced northward. The map shows a large ice block hole between Ghent and West Ghent at an elevation of 350 feet. Due north of this locality about 10 miles is a large ice block hole of irregular shape nearly 2 miles in length in which lies Kinderhook lake, with its water level at 288 feet. The surface of the neighboring plain at Niverville is 328 feet. South and east of this ice block hole are depressions indicating the deposition of the surrounding sediments in the presence of melting blocks of ice. Similar small kettles are shown along the Valatie kill north of Kinderhook lake, and they occur also northwest of this lake at elevations between 280 and 340 feet according to the map. I have interpreted these phenomena as indicating that the eastern border of the ice at the Newburg stage or approximately at that stage extended along the line of these kettles and that the marginal ice was suffused with drift washed in along the border. It also appears that the later Albany waters could not have deposited sand and clay so high as these kettles else the depressions would have been filled. Kinderhook lake is decisive on this point.

Schodack glacial terrace. The above described deposits are continued on the north in the deltalike terrace of the Moordener kill. The upper terrace between Schodack depot and Schodack Centre rises to the hight of about 340 feet on its outer margin overlooking the lower terrace about Albany. Its inner margin is about 360

PART OF THE CATSKILL QUADRANGLE



LEGEND

Kettle terrace.

The pits, some of them with lakelets, are the sites of buried or outlying blocks of the ice-sheet, surrounded by the wash of gravels and sands. At this time the region on the east of the terrace was free from the ice, but that on the west must have been covered by it. The low ground at the west base of the terrace was apparently invaded by the shallow waters of Lake Albany

THE LIVINGSTON LATERAL MORAINE TERRACE

Formed on the eastern margin of the Hudson Valley ice-tongue

Scale $\frac{1}{62500}$ — 1 0 1 2 Miles

Contour interval 20 feet

Datum is mean sea level

feet above the sea. The terrace has a distinct westward extension along the path now followed by the Moordener kill, and has the form of a delta built by this stream at this level but at a time when remnants of the ice sheet still filled the bottom of the Hudson valley in this region. The evidence of this lingering ice is found in several remarkable kettle holes bordering the stream and in the contour of the western front of the terrace which is strongly suggestive of an ice contact slope [*see* pl. 8].

The kettle holes in the delta are broad deep depressions with ice contact slopes having narrow gaps in each case on the side toward the stream. Two of these kettle holes are north of the stream, a large one forms a deep reentrant on the south bank. This last kettle hole is depressed below the rim of its outlet gap but contains no standing water because of the permeability of the gravels. North of the Moordener kill and south and west of the Schodack road, kettlelike depressions in the plain indicate the extension of the ice remnants in that direction. Yet another broad depression lies on the north side of Vlockie kill at the base of the hilly ground; and still another depression occurs to the south of this brook.

Moordener kill has partly dissected this high level delta terrace and sunk its bed on the rock at three points between 120 and 150 feet above the sea. The thickness of the deposit is evidently about 100 feet.

Northward the delta terrace is traceable as a narrow shelf of drift to and beyond East Greenwich, where on the west of the turnpiked road kettle holes again appear indicating deposition in the presence of masses of ice. Beyond this point, north of Mill creek, the terrace is not definitely traceable. Southward the terrace front retreats toward the hilly country and is not more than ½ a mile wide where traversed by Vlockie kill, and it extends south of this stream between the low till-covered hills to an apparent end at the southern limit of the Troy quadrangle.

The slope by which this terrace drops off to the level of the broader and smoother terrace adjacent to the Hudson river is singularly regular specially between Moordener kill and East Greenwich. At a few points along this slope the topography bears indubitable evidence of having been molded in the presence

of a glacier margin. The beachlike evenness of the contour of the base between the 260 and the 300 foot lines, the overlapping spitlike projection extending from the base of the upper or Schodack terrace southwestward on the north bank of the Moordener kill to Schodack Depot, as well as the character of the drift along this slope at the level named, are strongly suggestive of a water level between 260 and 280 feet. Between these two levels the bed rock is exposed in low ledges as if from the effects of wave stripping. The annexed diagrammatic section east and west in the latitude of Vierda kill illustrates the relation of the Schodack terrace to the lower terrace confronting the Hudson gorge.

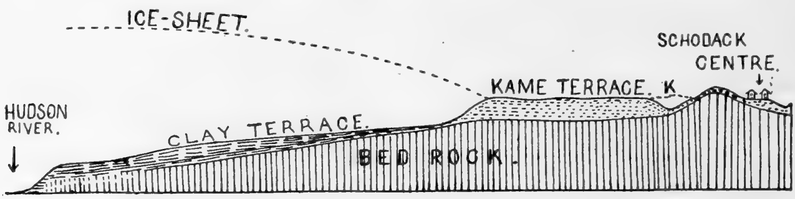
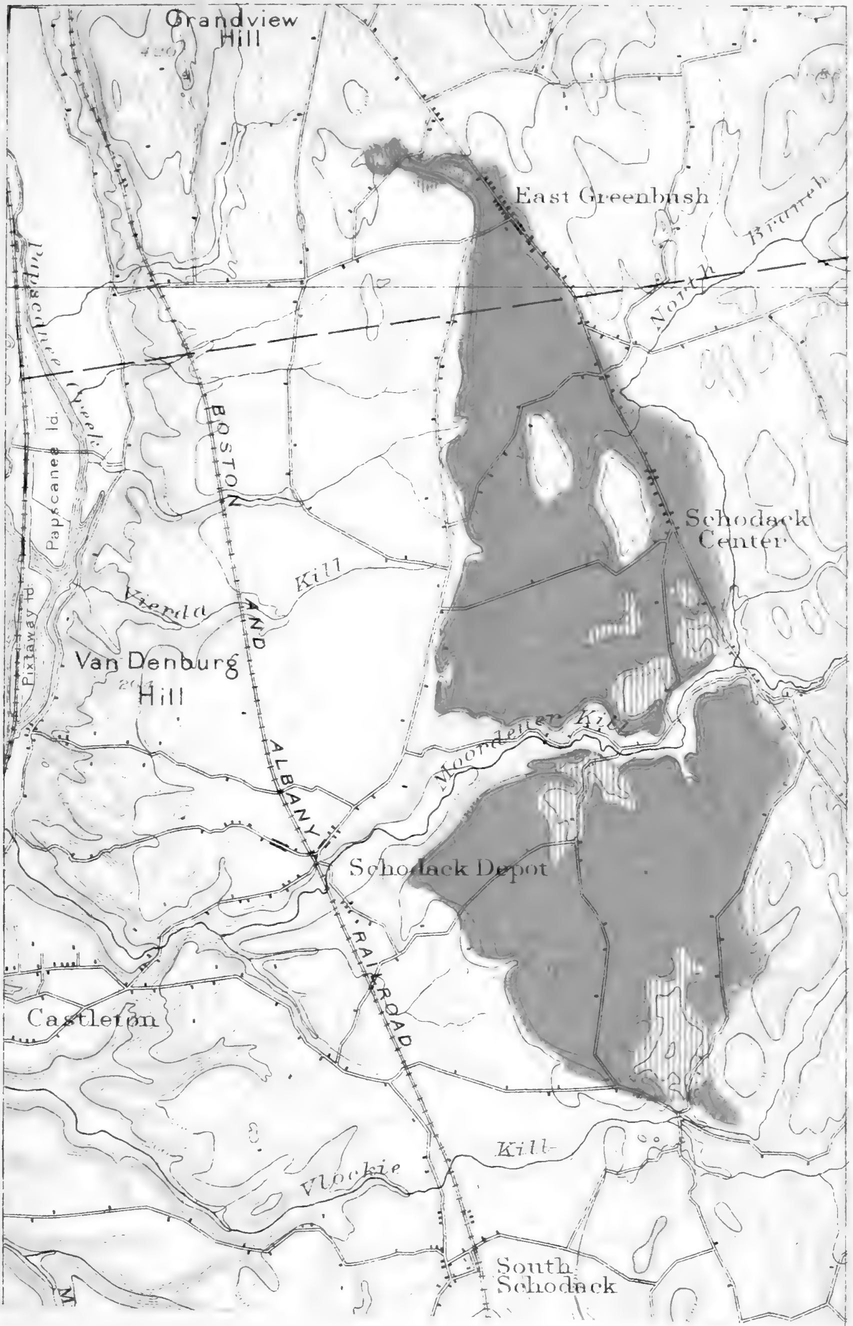


Fig. 14 Cross-section of delta terrace, near Vierda kill. K, kettle hole

South Bethlehem terrace. On the opposite or western side of the Hudson valley there is a small dissected terrace at the mouth of Oniskethau creek with its base resting on the old valley floor of the Hudson just west of the village of South Bethlehem. This terrace likewise rises abruptly from the low broad clay plain adjacent to the Hudson trench to the hight of 260 and 280 feet above the sea. The large remnant of the deposit on the south bank of the Oniskethau is totally unlike an ordinary delta built in an open water body. The outer margin overlooking the clay plain has a raised rim with a gentle slope for some rods back to the westward or upstream and the surface of the terrace is strewn with angular blocks many of which have now been gathered into fences. The long bar rising to the hight of 260 feet on the north bank of the stream is gravelly on its western slope but coated with till on the slope toward the valley in the manner of an ice contact. In fact, every feature of the outer slope of this terrace indicates that the deposit was made in a depression between the hills and the ice margin when the glacier filled the

PART OF THE TROY QUADRANGLE



Hudson valley in the manner shown in the accompanying diagram [fig. 15].

It will be noted from the account which follows that these two terraces accord closely with the level of free deltas farther north. If these terraces were made in open water, it must have been during a temporary retreat of the ice tongue which lay in the valley, a readvance of which produced those aspects of the deposits as they now exist which point to deposition of the materials about their outer margins in the presence of ice. The limit of construction by water action in the South Bethlehem terrace was apparently a local affair. This appears evident from tracing this ice mass around the base of the hills bordering

Fig. 15 Cross-section of glacial deposit in Hudson valley from Schodack Depot to South Bethlehem, showing glacial terraces where the Moordener kill and Oniskethau creek mouthed on the ice border. The rock terrace is covered by clays of later deposition.

the west side of the Hudson valley past Feura Bush and New Scotland to the upper valley of Vly creek southwest of Voorheesville. In this region the escarpment of the west wall is indented by the New Salem valley drained by the creek named. When the ice retreated from the upland and its southern margin lay at this point, a barrier was created across the northward drainage of the Vly creek, holding up its waters in a temporary lake probably to the hight of the divide between it and the Onisketbau, about 430 feet above the present sea level. The west branch of Vly creek (see the Albany quadrangle) flows in a depression approximately along the line of the ice front at this stage. From the south bank of the creek, rises a terrace of glacial materials which attains an elevation of 400 feet, at a point west of the junction with the south branch of the same stream. This plain is a rude delta built into the lake at this stage. The outflow of this lake took place apparently through the Onisketbau and thence contributed somewhat to the terrace building at South Bethlehem. These trivial details have been presented as showing that deposits which are here indicative of

water deposition at levels 120 feet apart were presumably contemporaneous and made in the presence of ice-constrained waters above the level of the sea.

Kettle terraces of Sandlake and Poestenkill. From 7 to 12 miles north and east of the Schodack deposits and at a much higher elevation, the topographic map in the towns of Sutton and Jennings shows contemporaneous glacial terraces developed along the course of the Wynant kill and Newfoundland creek. The surfaces of these deposits are at various levels from 520 to 720 feet. They clearly pertain to an earlier ice margin than that nearer the river at Schodack and are far above the water planes of the valley subsequent to the disappearance of the ice sheet over the region south of Albany; but no examination of them has been made in the survey on which this report is based.

Having followed now from Newburg to the vicinity of Albany a series of deposits contemporaneous with the retreating ice sheet or tongue in the Hudson valley it is necessary to note other deposits in the same portion of the valley but nearer the river or in a doubtful relation to the ice sheet. These notes are concerned with a few typical cases only.

Arlington clay deposit near Poughkeepsie. South and east of Poughkeepsie as noted by Ries there are clays which are worked at Arlington with their surface at or about the 180-foot contour line. The precise stage to which this deposit belongs has not been definitely determined, but its position and association with the intraglacial debris which covers the terrace of the Hudson from the lateral terrace delta at New Hamburg northward shows that it is at least as old as the occupation of the valley by the Newburg ice remnant, but it may be an earlier body of clays. That the clays do not belong to the Albany stage is quite evident from the general distribution of glacial deposits in the vicinity.

Port Ewen deposits. Port Ewen lies on the south side of the mouth of Rondout creek. The terrace deposits here have an elevation of 150 feet, consisting of boulder clay below with striated stones, the blue clays and sand at top. The underlying till is very stony and gravelly, and may be seen in the bank as high as 30 feet

above sea level. Its contact with the overlying clays was nowhere well exposed at the time of my visit.

The top sands appear to follow the clays naturally as the result of shoaling water and the pushing out of the ancient delta of Rondout creek. It is noticeable that the sand beds have been cut out from time to time to the depth of 3 or 4 feet and as rapidly filled in by the continued transportation and deposition of sands from the same general source. The dominant cross-bedding in these sands displays a southeastward dip, but sections are exposed in which the opposite direction may be observed, from which it is to be inferred that the currents which carried the sand were subject to changes in direction. The almost complete absence of pebbles in this deposit is indicative of weak bottom currents at this level and as well the want of floating ice by which such coarse particles are often distributed.

Rondout terrace deposits. One sees two terrace levels about Rondout. A lower one is very well marked north of the ferry landing at about 50 feet above tide, the higher one occurs at 200 feet. A trench 4 feet deep in fine sand was exposed at the time of my visit at 51 Abruyn street near East Union street on the 50 foot terrace. This lower terrace is so much built over that its precise nature is in doubt. Toward the rock cliff and just north of the old cement quarry drifts, sand, composed in part of white quartz grains and hard shale bits, occurs as high as 100 feet and fragments of probably the same deposit rise to 120 feet.

Toward the north the 200 foot terrace shows gravel under the clayey sand of its upper section. So far as I was able to observe the clay is wanting in the immediate vicinity of the mouth of Rondout creek on the north; but at Kingston Point the clay appears and just south of the Terry hill triangulation station extensive clay banks have been opened.

In the Hutton Co.'s yard there is a topping of from 35 to 40 feet of sand, sometimes cross-bedded, with dip of cross-beds to the northeast. A lower part of this sand may fairly be described as clayey sand, pointing to a gradation into the purer clays beneath.

The clays are blue, with fine, white, micaceous sand bands varying in thickness from ¼ inch to 1 inch or even thicker. Thin

bands of the sand may be seen separated by layers of clay from 4 inches to 1 foot thick.

In the Terry bank, the top of the terrace is delimited by the 220 foot contour line. The clays have accumulated against a perpendicular wall of the limestone, and there is a topping of over 30 feet of sand. The clay bands in this bank are only about half as thick as those in the yard farther south and nearer Rondout creek.

The dominant southeastward dip of the cross-bedded sands on the south of Rondout creek at Port Ewen, and the northeast direction of the similar structures on the north of the mouth of that stream indicate the radial development of the clays and sands about Rondout through the discharge of the creek into a body of water whose surface was at least 200 feet above the present sea level at this locality.

For several miles north and south of Kingston and Rondout the 200 foot contour line marks the break between the upper surface of the flats of clay, sand, or gravel which encompass the bases of the rocky ridges and lesser hills of bed rock.

Along the creek west of Kingston, gravels with coarse boulders rise above flood plain level. In a section 30 feet thick, a stratified gravel knob with boulderets up to 2 feet in diameter was seen capped by clays and sands, the summit of which did not rise above the 200 foot line. These coarse cobblestones are doubtless to be attributed to deposition by streams from the melting ice and therefore may be referred to an earlier epoch than that of the clays and sands.

We return now to the glacial deposits underlying the clays.

Meadowdale stage. About 1 mile south of Meadowdale on the western border of the Albany quadrangle there is a local morainal deposit with knobs and basins partly till and partly washed glacial drift the stratified components taking on a terraced form between the 280 and the 400 foot contour lines. Deposition evidently took place in the presence of the glacier immediately after the retreat of the ice from the New Salem lake barrier. This moraine or kame moraine merges eastward into a broad sand plain at about the 360 foot level. Kames and ridges of gravel outline its margin on the north. Across a depression on the east of it another small plain has developed at about the 240 foot

Plate 9

Stream-deposited glacial gravels and sands at North Albany; beneath the Albany clays

level. These three deposits are traversed by the road from Voorheesville to Meadowdale.

This falling off in the level of terrace and sand plain building from west to east, from 380 to 360 and then to 340 feet indicates a lowering of the water level dependent on the opening of lower gaps between the ice front and the escarpment on the east. These levels of construction so like the effects of ice-confined waters are within the zone of altitude affected by ice on the east bank of the Hudson in the Schodack district and lie above the broad clay plains immediately west and south of Albany and are thus clearly above any marine limit which has left a mark in this field.

At South Bethlehem the upper level of these Albany clays is 200 feet, near Voorheesville it is about 300 feet; in the dunes south of Schenectady the hight is about 360 feet, the precise elevation having been affected by the erosion and deposition of the fine sands by the action of winds in the postglacial epoch. The rate of fall from Voorheesville to South Bethlehem is about 1 foot to the mile for a distance of 10 miles, from the vicinity of Schenectady to Voorheesville a rate of somewhat less than 1 foot in a distance of 7 miles.

North Albany gravels. Between Albany and Loudonville on the north side of Patroons creek there is a high ridge of morainic aspect with long kettles and a boulder-strewn surface. These general characters are traceable northward beyond Ireland Corner. This deposit certainly antedates the Mohawk delta stage, and indicates by its form and structure that it was made during the occupation of the valley by ice, and is undoubtedly to be correlated with the lateral glacial terraces at Schodack and South Bethlehem or to a slightly later stage. The rise of the ridge to 360 feet or over in close accordance with the level of the Schodack terrace suggests that the remnant of the glacier in this district may have been sheeted over with flood plains of gravel, while the depressions were filled with the same material.

At the southeastern foot of this ridge in North Albany the clays are seen resting unconformably on these older glacial gravels. The gravels are locally very coarse and bouldery, layers of small boulders up to 1 foot and even 15 inches in diameter being seen well up in the section. The beds have a strong dip toward a depression on the north of this locality as if they had settled.

The relation of the clays to the older gravels shows that the gravels were cut off on the south by running water so as to form a well defined bank. Down this bank cobbles and boulders rolled. Subsequently clays began to deposit in horizontal layers against the bank, indicating a change from powerful streams of water running over the surface and cutting deeply into its drift deposits to a time of quiet silt-laden waters.

Further indications of the mode of building of these older gravels occur in a pit in the same vicinity. The structure is that of an aggraded deposit of gravels with extremely coarse lenses

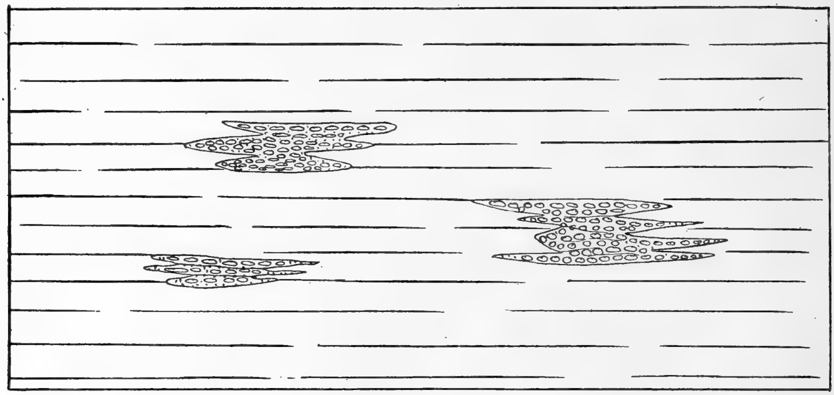


Fig. 16 Cross-section of aggraded glacial gravel deposit at North Albany, showing lenses of coarse gravel in old stream bed. [*See also* pl. 9]

showing where the stream bed as it wandered from point to point in the building up of the deposit happens to appear in the cut. The above figure illustrates the general cross-section of the pit.

Mohawk delta. The extensive sand and clay plains developed on the Albany and Schenectady quadrangles in the towns of Bethlehem, Guilderland, Watervliet, Niskayuna and Rotterdam, south of the Mohawk river, form an ancient delta of that river and are the most extensive deposits of this nature in the Hudson if not also in the Champlain valleys. The deposit, clayey below and near the Hudson gorge, gives way to sands toward the northwest and in the upper sections. Along the Hudson gorge the deposit fills in depressions in the rock bench and mantles this older topography except at such localities as the Abbey at Glenmont. The average elevation of the surface from Albany south-

ward at the brink of the gorge is now 200 feet. The surfaces rise northwestward to an elevation of about 350 feet near Schenectady. Between Schenectady and Albany the surface is mantled with extensive dunes of fine sand whose elevation rises to 400 feet, causing a postglacial elevation of the surface in this district by accumulation at the expense of the elevation of the deposit farther west near Schenectady. The Mohawk river now flows on the north of this delta. As will be noted in the account of the region north of the river the delta appears not to have been deposited in that district for the reason that it was covered by ice at the time the delta was building.

The present course of the Mohawk from Schenectady eastward is in a rock gorge separated, along the northern border of the town of Niskayuna, from the delta plain by till-covered ground rising above the delta level. At Alplaus[1] the Ballston channel extends to the north and east. The history of this network of drainage lines including the Ballston channel, and the Round lake drainage, has not been fully investigated. It seems clear however that the Mohawk delta began to make when the retreat of the ice sheet opened a passageway along the area covered by this deposit, and that the waters coming through the Mohawk valley pursued this course while the delta was building. At a later time when the ice melted away from the northern border of Niskayuna it left a tract at a lower level than the surface of the delta on the south and the river naturally began to flow along the course it now pursues below Schenectady.

It is difficult to fix any definite water level by the present elevation of the Mohawk delta. Certainly its lower clayey border near the Hudson river was under water during the stage of deposition. Presumably its upper stretches were not under water except in floods.

From a comparison of the neighboring evidences of shore lines indicated by small deltas and the upper limit of clays, I have hesitated to place the average water level above 320 feet.

Summary of the Newburg and related stages. Though the western border of the glacier which lay in the middle Hudson valley between Albany and Newburg has not been definitely

[1] This is the present corrupted spelling of the place originally called Aalplaatz—a good place for eels.

traced, the evidence on the east of the valley in the form of lateral moraine terraces shows that a long tongue of ice lay

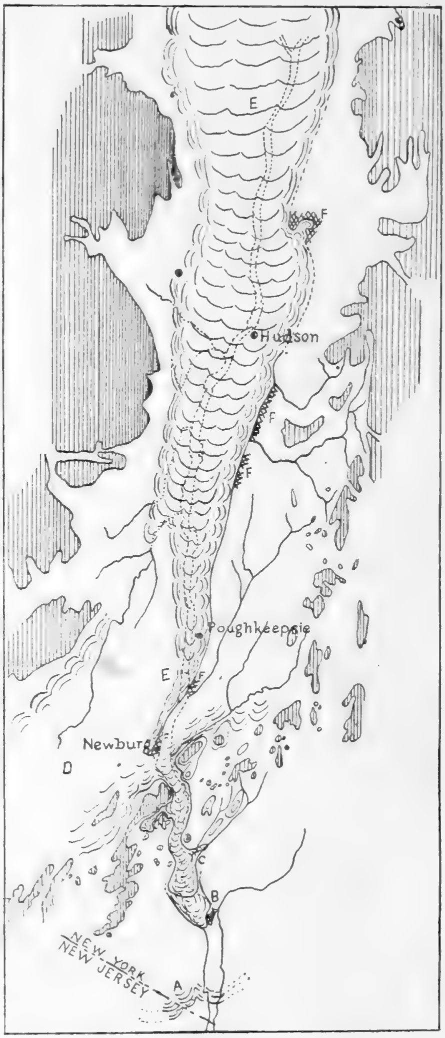


Fig. 17 Sketch map designed to show manner in which the glacier retreated in the Hudson valley. A, ice front at Tappan N. Y.; B, protrusion of glacier through the Highlands to Croton point; C, a later stage in the same; D, same stage as C when the ice still filled much of the lowland north and west of the Highlands; E, the Newburg stage. The western limits of the ice at the Newburg stage are conjectural. Definite margins of the ice on the eastern side are shown by ice contacts at F, F, F. Vertical ruling in areas over 1000 ft in elevation

over the gorge and for some miles east of the present river holding up the drainage of the side streams for a time, giving a more or less definite belt of deposits traceable northward as

far as the vicinity of Troy. The kettle holes in these terraces mark the sites of blocks of ice which melted out after the deposition ceased. Had the blocks melted out before deposition stopped the hollows thus formed would have been filled with gravel and sand. The deposits likewise serve to show that since the kettles took on their present shape the region in which they occur has not been subjected to sediment-bearing waters, and hence it is to be inferred that the lake stages which developed in front of the retreating ice sheet in the Hudson valley did not rise so high as these deposits. How long the buried ice remained after the withdrawal of the glacier from the terraces is not precisely known. But it does not appear likely that the ice remained in these positions during the subsequent lake stages whose duration as will be seen from the evidence here submitted must have been considerable.

North of Newburg the immediate banks of the Hudson exhibit stages of retreat of the ice in coarse gravels as near Staatsburg and Hudson with correlated finer deposits on the south of each such section, separated in many instances by banks of the old gorge in which till alone mantles the wall.

Where large streams enter the gorge as at Rondout, Kingston and Catskill there are also deltas with appropriate deposits. Clays are present in the southern part of the middle Hudson valley but they are subordinated to local deltas and to local stages of deposit in front of the retreating ice as is also the case throughout the river valley south of Newburg to the sea.

From somewhere near Kingston and Rhinebeck, clays begin to form a mantle along the rock terraces of the Hudson covering all the coarser deposits made in the gorge or over the immediate banks during the retreat of the ice from this vicinity northward to the Mohawk. This limitation of the clays was early recognized by Mather. The body of the clay is evidently to be correlated with the Mohawk delta and that with the discharge of a large body of water into the Hudson valley from Lake Iroquois on the west, a matter which is considered more in detail in a following chapter on Lake Albany.

Later stages of change in the valley are shown by low terraces partly within the gorge of the river and by the excavation which has taken place in that trench.

Chapter 4

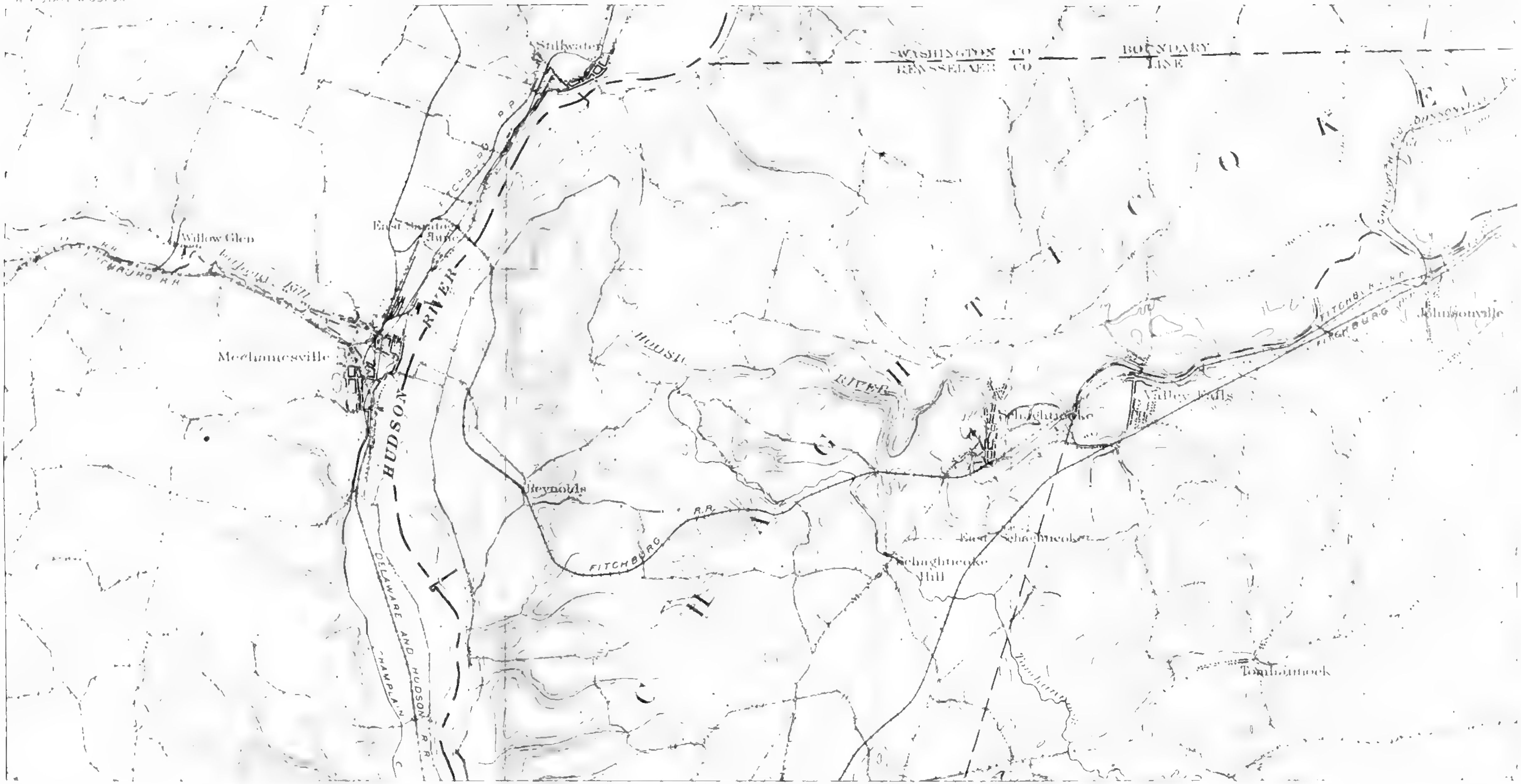
GLACIAL DEPOSITS OF THE UPPER HUDSON VALLEY

From Albany northward the precise position of the ice front at its several successive stands in the retreat is frequently a matter of conjecture in the immediate vicinity of the Hudson gorge owing to the extensive water action which has followed the retreat of the ice from this district. In the following notes the geographic order is generally adopted as the basis of description. At many of the localities the deposits recorded and the topographic features noted pertain to widely separated events.

Hoosic delta. The Hoosic, the largest tributary of the Hudson river from the mountainous belt on the east, enters the Hudson gorge a few miles north of the mouth of the Mohawk and nearly opposite the Round lake channel at Mechanicville. The approximate apex of this delta is at Schaghticoke at an elevation of 360 feet. The Hoosic has sunk its bed deeply within the delta and the clays which border the Hudson gorge, turning to the northwest, a course which it has pursued since dissection began. There is a probable ancient temporary channel on the southeast border of the delta followed by a railroad between Melrose and East Schaghticoke stations. The bottom of this trench is about 350 feet above sea level. This rather marked deflection of the stream as it now runs to the north can not conclusively be stated to be due to the same cause as that which has been advanced for the position of the Mohawk on the northern side of its ancient delta. The dissection of the Hoosic delta is considered on page 200.

Above Schaghticoke with the falls in the stream there are two notable features: on the southeast the flats of Tomahawk creek extending nearly to Raymertown and on the northeast the glacial terraces bordering the Hoosic river to and beyond the limits of the Cohoes quadrangle. These terraces with an elevation of about 400 feet at Valley Falls, 4 miles farther east rise to 420 feet. They are sharply trenched by the Hoosic with lateral gullies. They are evidently flood plain deposits or parts of a valley train whose surface from Schaghticoke eastward lies above the level of the water body into which the river at one time discharged. Their levels have therefore been neglected in the consideration of the problem of water levels in the Hudson valley.

PART OF THE COHOES QUADRANGLE



Anthony kill joins the Hudson through a trench cut in the Albany clays and drains an unfilled depression on the west (see Plate 1). The clay plains on either side of the Hudson, much dissected by streams, are characteristic features of the bottom of Lake Albany.

THE DELTA OF THE HOOSIC RIVER AND THE OUTLET OF ROUND LAKE (ANTHONY KILL).

Scale $\frac{1}{62500}$

1 0 1 2 3 4 Miles

Contour interval 20 feet

Datum is mean sea level

The delta of the Hoosic is largely clay and has been deeply dissected by streams (see Plate 25). The broken terrace of gravels on the north bank of the river from Valley Falls to the limit of the map is a remnant of the bed of the river formed after the freeing of the stream from the ice-sheet.

West bank of the Hudson between Schuylerville and Stillwater township. South of the valley of the Fish creek, the Hudson rock terrace extends back from the river as far as Quaker Springs with a width of about 2 miles. Clays or stony clays rise in flattish, stream-cut plains to the 300 foot contour line, where the Hudson slates meet the folded sandstone beds which form the belt of low hills on the east of Saratoga lake.

Southward toward the Stillwater line gravel and sand occur in beds as much as 10 feet thick over the clays. Near the river the sands suddenly cease, giving rise to a low terrace at the base of which small springs break out on the surface of the clays.

Farther north there are broad tracts in which the Hudson slates are practically bare of drift, such clays as appear at the surface being due to the disintegration and decomposition of the highly tilted slates. Over this eroded surface large, round concretions derived from the slates occur as boulders. Such concretions may be seen in place in the railroad cut north of Coveville and which when loosened from their bedding places might be mistaken for glacial erratics. These driftless strips near the river evidently demand the action of a strong current flowing through the Hudson valley apparently before the complete re-excavation of the gorge in its glacial and later clay filling [*see* p. 193].

Kendrick's hill. In the southeastern corner of Wilton township a hill, of at least glacial materials so far as the road cuts show, rises to three summits, forming a conspicuous object on the general level of the broad sand plains between the Hudson at Schuylerville and the base of the Adirondacks. About the northeastern slope the hill has a morainic aspect. In places it is enveloped with driven sand. I found no traces of shore lines on Kendrick's hill. In fact its base lies above the 320 foot contour line.

Saratoga lake region. Saratoga lake as in the case of Round lake occupies a depression in the bed rock but in this case of far greater extent than the area of the lake for much of the depression has been filled by glacial deposits. That the ice sheet is partly if not wholly responsible for the unfilled condition of this ancient basin is indicated by the form and distribution

of the sands and gravels and underlying clays in the flat topped glacial deposit which borders the west shore of the lake.

This deposit lies mostly between the 260 and 280 foot contour lines. Its steep sides have probably been cut back somewhat by the lake when the water was at a higher level and covered the low ground of Bog Meadow brook on the west.

This 260 to 280 foot terrace is well marked in Fish creek valley. Extended gravel and sand plains of about the same level occur south of Saratoga Springs, the whole presenting a complex series of deltas apparently built in the presence of lingering blocks of ice. Till the detailed study of these deposits and their final mapping has been accomplished it will not be possible to state just what relations this area has to the Hudson trough on the east of it. It is evident though that the clays on the Hudson rock terraces were not abundantly deposited either in Fish creek valley or over the Saratoga lake district. This may have been because the lake region was so far from the mouths of clay-contributing streams and out of the drift of currents that clays were not brought to the district. There is no evidence of the clays having been swept out of the valley.

That clay-depositing waters occupied the region as high as the 300 foot contour line is shown by the character of the debris at the base of a cliff on the east bank of the lake 1 mile east of Saratoga lake station. Here the under, older part of the talus is grayish, clay-stained debris of the Hudson river rocks. Above and outside of this is a more modern talus of clean, black fragments of the cliff above, this newer talus accumulation being about 4 feet thick. It is to be assumed that the older talus at least as high as the 300 foot line accumulated in the waters which deposited clays at that level to the eastward on the Hudson rock terraces.

The ice remained longer over the depressions occupied by Saratoga and Round lakes than it did in the Hudson valley immediately east of this district. The large streams coming into the Hudson valley from the open ground on the east probably favored the melting of the glacier more rapidly on the side where their water coursed along the ice margin.

MIDDLE THIRD OF THE SCHUYLERVILLE QUADRANGLE

Showing a part of the region south of Plate 12

THE DELTA OF THE BATTEN KILL AND THE COVEVILLE CHANNEL.

Before the Coveville outlet was used by the discharge from Lake Vermont, a powerful current swept southward over the west bank of the Hudson near Quaker Springs. The Hudson gorge in this area was still filled with drift and clays.

Scale $\frac{1}{62500}$

2 Miles

Contour interval 20 feet

Datum is mean sea level

The delta of the Batten kill, now dissected by the stream, forms the plains about Bald mountain and southwest of Greenwich. The delta originally extended across the Hudson gorge as far as the Battlement monument

Coveville

Former buried

The precise boundaries of the retreating ice sheet are obscured by the abundant deposits of sand and clay and by the further blowing of the sands by winds in the district between Saratoga and Gansevoort, so that in spite of several days spent in the endeavor to trace the limits of retreating masses of ice I was unable to get a satisfactory idea of the precise alinement of the ice front across the valley in this field.

Delta of the Batten kill [*see* pl. 11]. The Batten kill debouches into the Hudson river at Schuylerville near the northern limit of the main body of the Albany clays. A broad delta of gravels and sands caps the clays on the east bank of the Hudson stretching back from the gorge to the low range of hills which forms the eastern border of the Hudson valley. The Batten kill passes westward through this range at Greenwich where the terraced apex of the delta rises between 340 and 360 feet. Along the western base of the hills the delta extends south of the stream as a broad plain for nearly 2 miles. Three points leveled on the inner upper margin of the deposit near the river are according to the state map at elevations of 348, 344, and 358 feet respectively, from which 350 feet may be taken as the approximate upper level of the delta. Outward the delta falls off to the 320 foot line with a very gentle slope and then descends more rapidly to the 300 foot level. North of the stream at the base of Bald mountain a considerable stretch of the delta plain lies between 300 and 316 feet above the present sea level. Since the outer margin of the delta where it falls off most rapidly is a better index of water level than the apical portion of the deposit merging into the flood plain level which was probably built above water level, it appears that the water level at this point is approximately 320 feet above sea level. Southward of the delta the clays and sands meet the base of the hills at about the same hight.

Northwest from Bald mountain and between the 300 foot level and the river lies a lower plain whose surface is between the 220 and the 240 foot contour lines, a level which is well marked at several places on either side of the Hudson gorge for 5 or 6 miles north and south of Schuylerville, but one which is very close to that of broad areas of the bed rock in the immediate

vicinity of the river. A broad shelf at this level borders the Moses kill where that stream enters the Hudson gorge. In such cases the drift deposit may well depend on the bed rock for its position.

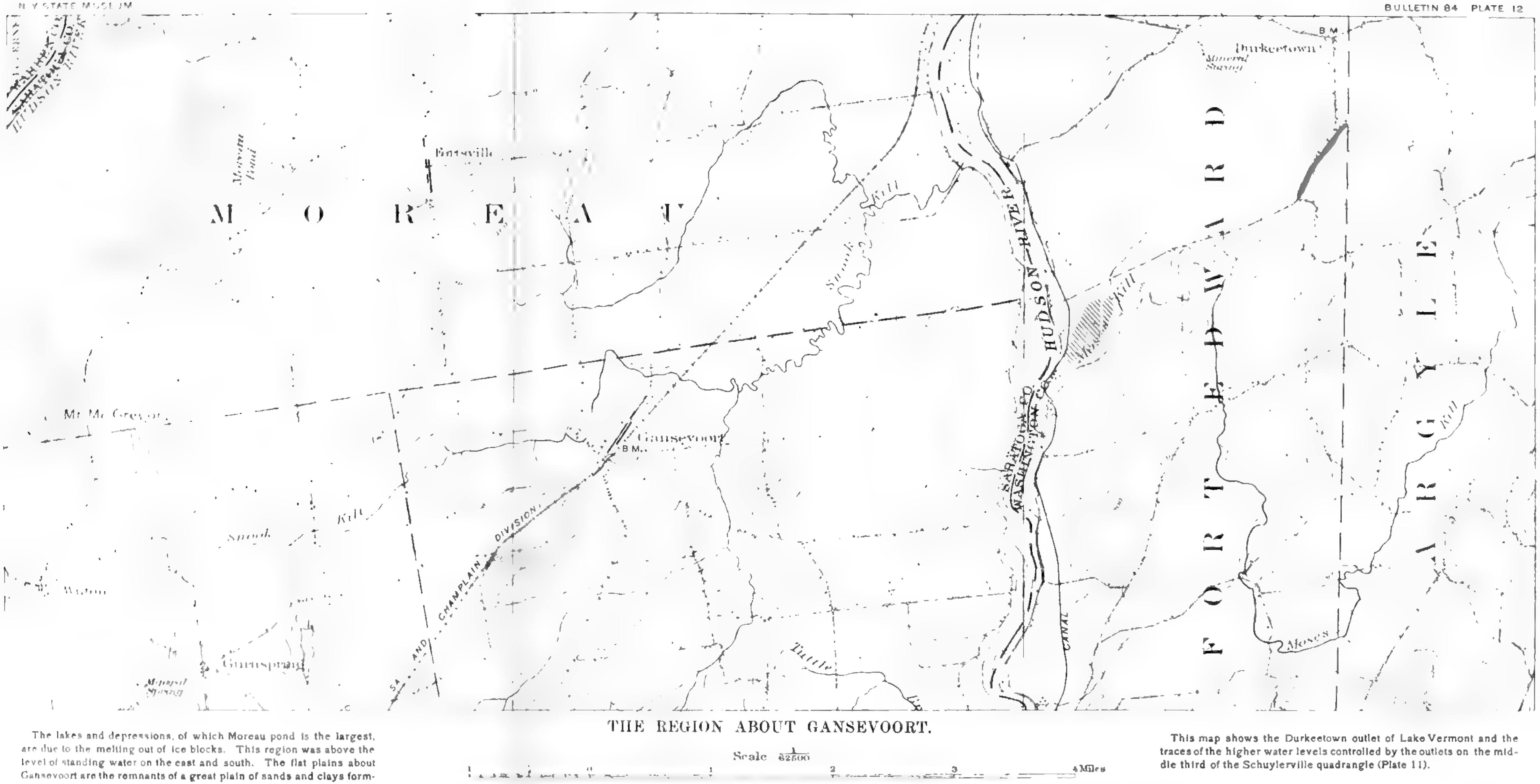
The erosion forms of the Batten kill delta along the bank of the Hudson opposite Schuylerville form a conspicuous feature in the landscape and the topography of this side of the river is in strong contrast to the west bank on which the delta sands appear in the vicinity of the Saratoga Battle Monument.

The clays which underlie the delta appear throughout the district below the 300 foot level.

Durkeetown terrace [*see* pl. 12]. One mile south of Durkeetown in the northeastern corner of the Schuylerville quadrangle a ridge rising above the 300 foot contour line extends south-southwestward for 1½ miles, bounding the Fort Edward district on the southeast. On the western slope of this ridge between the 280 and 300 foot lines is a weakly developed terrace of water-worn gravels. These are coarse cobbles on the northeast above the road but become fine gravels toward the southwest at the crossroads. The general appearance of the deposit is that of a beach on which the materials have traveled southwestward. There is nothing in the frontal slope of the narrow terrace to prove that the margin of the ice remnant lying over the Fort Edward district confined the deposits as in the case of many likewise narrow terraces at higher levels along the base of the mountain on the west of the same district. The terrace may be taken therefore as the index of water level during the closing stages of the deposits of the Albany clays when the ice had melted out at least as far north as this locality. On the east of the same ridge is a flat floored valley at about the same level, one which corresponds with the upper limit of the clays over the western part of the Fort Ann sheet on the north and with the outward margin of the delta of the Mettawee at West Granville.

Fort Edward district. At the northern border of the Schuylerville quadrangle the rock terraces of the Hudson gorge retreat east and west, and the gorge widens out into a depression traversed by the present but newly established course of the Hud-

NORTHERN THIRD OF THE SCHUYLERVILLE QUADRANGLE
Showing the Hudson Valley south of the district mapped on Plate 13, and north of that on Plate 11



THE REGION ABOUT GANSEVOORT.

Scale $\frac{1}{62500}$

Contour interval 20 feet

Datum is mean sea level

Terrace or beach (?).

Water-worn rocks.

The lakes and depressions, of which Moreau pond is the largest, are due to the melting out of ice blocks. This region was above the level of standing water on the east and south. The flat plains about Gansevoort are the remnants of a great plain of sands and clays forming a delta under the water level T—U of Plate 28.

This map shows the Durkeetown outlet of Lake Vermont and the traces of the higher water levels controlled by the outlets on the middle third of the Schuylerville quadrangle (Plate 11).

son from the base of the Adirondacks to Fort Edward and by the older channel of Wood creek. It will be convenient to treat of the glacial features of this district in what appears to be the order of their sequence in time which as everywhere in the Hudson valley is quite uniformly in a descending order as regards the vertical distribution of the deposits. These deposits consist of high level terraces with invariably an ice contact face confronting the Fort Edward district, and a lower series of deposits made in open water; while at still lower levels there is the evidence of erosion by running water as in the gorge farther south.

Of the glacial terraces, the highest and oldest as well, lies within the Adirondack canyon of the Hudson. This deposit rises to the

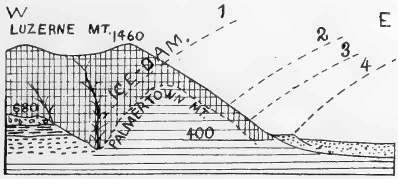


Fig. 18 Terraces in the vicinity of Palmertown mountain. On left hand is shown the Hartman terrace in the Hudson canyon. 1, 2, 3, 4, represent successive positions of retreating ice margin. At 4, is the kame terrace at eastern base of the mountain overlooking the Fort Edward district.

hight of 680 feet above the sea or about 400 feet above the bed of the river at its base. The small hamlet of Hartman postoffice is located on its top. The river has cut away the eastern front of the deposit giving a partial exposure of coarse gravels about 200 feet thick at base, over which come stratified clays and sands, above which in turn occur gravels with a rude kame topography, the whole showing a time of torrential currents in the canyon followed by lacustrine conditions with the deposition of clay in the gorge to a hight fully 500 feet above the present sea level; then a return of the ice in the coarse glacial detritus which caps the clays. The entire series is evidently earlier than the deposits which occur outside of the mountainous belt over the Fort Edward district and therefore need not be taken further into account in an attempt to fix the water levels which followed the disappearance of the ice from this region.

The glacial terraces which flank the mountain bases around Fort Edward are typically represented in that of Palmertown

mountain, a lower level about Glen Lake, a higher one at Patten's Mills on the north, and those of till at North Argyle and Evansville, which will now be described in the order named.

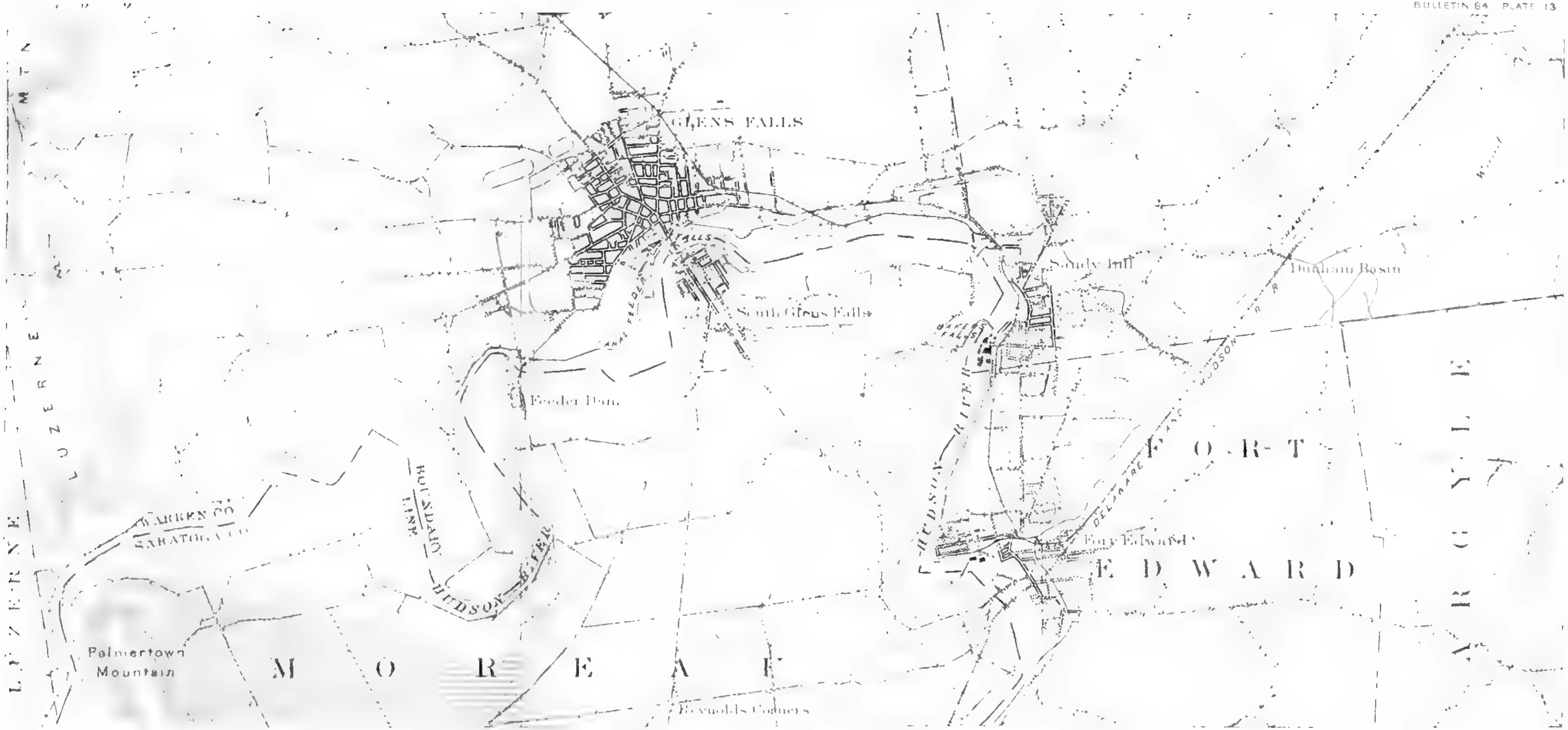
Palmertown mountain terrace [*see* Glens Falls quadrangle, pl. 13; *also* fig. 18, p. 139]. At the eastern base of Palmertown mountain there is a well developed terrace rising from 50 to 60 feet above the level of 400 feet. This terrace varies from $\frac{1}{3}$ to $\frac{1}{2}$ mile in width and near the Hudson river is cast into mounds and kettles proving its deposition in the presence of the departing ice sheet. In its northern part it is a typical kame terrace, and its eastern face or slope marks its original constructional limit against the border of the ice lying south of the present course of the river.

The materials of the terrace are exceedingly coarse cobblestones. With an ice barrier stretching across the mouth of the Hudson canyon, the water would be held back and caused to flow out at the lowest point of discharge which appears at this time to have been at Corinth. With the beginning of the retreat of the ice from the mountain wall the water would find an opportunity to pass along the eastern base of Palmertown mountain southward over the district about Gansevoort. It was apparently during this condition of drainage that the Palmertown mountain terrace arose, the terrace being the then bed of the river, and consequently above sea level.

Below and east of this terrace stretches another, a broad delta terrace, meeting the base of the earlier deposit at an elevation of 400 feet and probably marking a further marginal retreat of the ice sheet and a consequent lowering of the level of the glacial Adirondack-Hudson river [*see* fig. 20, p. 146].

Glen Lake kettle terrace. Small isolated terraces occur on the flanks of Luzerne mountain at the 500 foot and even higher levels marking the recession of the ice from the eastern flanks of the Adirondacks south of Lake George. It is not necessary to suppose that these deposits were ever much more continuous than they are now but below them at the base of the mountain extends one of the broadest and heaviest though not the longest glacial terraces seen anywhere in the Hudson valley. This deposit incloses Glen Lake, the central and largest example of

SOUTHERN THIRD OF THE GLENS FALLS QUADRANGLE



THE REGION ABOUT FORT EDWARD.

The geologically colored areas show successive stages of the retreat of the ice-sheet from Palmertown mountain and of the adjustment of the Adirondack Hudson river to the country freed by the ice.

The remarkable trough from Fort Edward to the northeastern corner of the map extends the Hudson gorge into the Champlain valley. Another trough, not so deep, is shown two miles east of Fort Edward. These troughs served as outlets to Lake Vermont

Contour interval 20 feet

Datum is mean sea level

Karne-Kettle terrace.

400-foot Delta Plain.

350-foot Plain.

a group of deep ice block holes and kame kettles, the most extensive in the entire length of the Hudson and Champlain valleys. This terrace begins on the south near the Hudson river in a narrow shelving deposit having an elevation according to the contoured map of about 420 feet. Two miles north of the Hudson river, the terrace or at least a higher level of the deposit attains an elevation of 482 feet. From this point the front of the terrace trends northeastward toward Round pond. Following along the base of Luzerne mountain, the level of the terrace rises to about 500 feet at the distance of 4 miles from the Hudson river; and at French mountain station the surface attains a hight of 548 feet.

The front of the terrace passing northeastward at a distance of 2 miles northwest of Glens Falls rises from 50 to 100 feet above the more thinly drift-covered surface at its base. The summit line of the terrace front rises to about 480 feet except where gnawed back by streams. This frontal slope is an ill characterized bluff neither lobate like the front of a delta built in open water nor with stratified gravels and sands standing at the angle of repose as in old stream-cut terraces now healed by gravitative slipping. The detritus at the front is perceptibly coarser than over the top remote from the brow of the slope and boulders are not uncommon along its extent, an assemblage of features, weaker than usual, but indicating undoubtedly the deposition of the materials of the terrace in an open space lying between the base of Luzerne mountain and the ice mass which still lay over the central part of the Fort Edward district. The large kettle and ice block holes representing outlying partially or wholly buried blocks of ice give strong support to this view.

Patten's Mills terrace. Between Patten's Mills and Sugar Loaf mountain in the southwest corner of Fort Ann township [*see* Glens Falls quadrangle, pl. 14], the border of the large mass of ice covering the Fort Edward district is again marked by marginal deposits but in this case on the north. These deposits assume the form of a high gravelly terrace attaining an elevation of about 520 feet near the southern margin, and sloping gently northward, partially inclosing in that direction a lake-

let between the 480 and 500 foot contour lines. This lakelet probably owes its existence to a remnant of ice on the north, separated from the Fort Edward mass during the stagnation of the ice south of the mountain passes. The nature of the bottom of the lakelet has not been determined but presumably there is bed rock close underneath. Both clays and bed rock appear eastward near West Fort Ann village in an extension of this ridge.

West of this outwash deposit and north of Queensbury village, there is developed between the 420 and 440 foot contours a deposit having in its highest part, where it confronts the northwestern margin of the Patten's Mills terrace, a large depression or kettle hole, shown by the contours on the Glens Falls sheet [*see* pl. 14]. This depression also shows that ice remained on the northern side of the Patten's Mills deposit independently of the evidence afforded by the small lakelet, and renders it probable that the slope of the ground in that vicinity from the 480 down to the 440 foot line is also an ice contact feature.

Morainal terrace at North Argyle. About 1 mile east of the village of North Argyle on the Fort Ann quadrangle is a rock ridge culminating in a point 1037 feet above the sea. The ridge extends northeast and southwest. At its western base overlooking the Fort Edward district from the east is a terrace of glacial till rising over 120 feet above the low ground at its base and having a maximum elevation at the summit of about 600 feet. This terrace appears to have been deposited by live ice and presumably is of somewhat earlier date than the stratified deposits found elsewhere on the north and west at somewhat lower levels.

North of Evansville in a similar position in relation to an older rock ridge and in nearly the same alinement a till terrace rises from the west bank of the Moses kill with its mass between the 500 and 600 foot contour lines.

None of these deposits afford other clues to the level of the waters which may have stood in this district subsequent to the disappearance of the sheet than by their negative character—the absence of later clays and wave marks over their surface. It

MIDDLE THIRD OF THE GLENS FALLS QUADRANGLE

THE GLEN LAKE AND OTHER SIMILAR ICE-BLOCK HOLES

And the Pattens Mills Terrace

Scale $\frac{1}{62500}$

1 0 1 2 3 4 Miles

Contour interval 20 feet

Datum is mean sea level

Ice-block holes

The Pattens Mills terrace

The "ice-block holes" mark the sites of remnants of the ice-sheet around which gravels and sands were washed.

The Pattens Mills terrace was formed on the northern margin of a part of the glacier covering the southeastern part of the area.

A part of the Fort Edward outlet of Lake Vermont is shown in the southeast corner.

is to be concluded from them that in this latitude neither large glacial lakes nor the sea rose so high as the surface of the lowest of these deposits. Much more detailed study of the region than I was able to give it in the search for water levels will be required in order to trace out fully the limits and history of the retreating ice mass of the Fort Edward region.

Fort Edward district below the glacial terraces. Below the marginal terraces above described as lying about the Fort Edward district, there are several well marked types of glacial deposits and a varied topography indicative of successive stages of development through deposition and erosion by water action. Not all of these deposits are pertinent to the inquiry concerning water levels.

From the vicinity of Glens Falls northwestward to the base of the Glen Lake terrace and thence northward and eastward

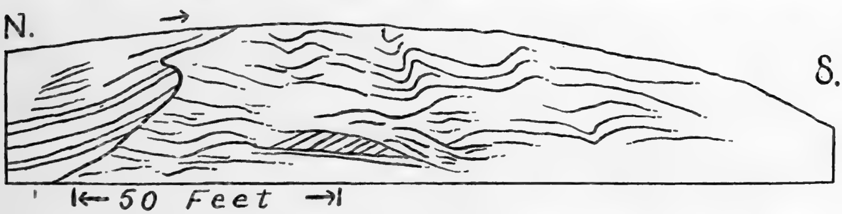


Fig. 19 Dislocated and overthrust clays, just north of Summit station, looking east, showing overthrust to the south

over the gently rolling country between Patten's Mills on the north and Argyle on the east, knobs and hillocks rising above the level of the clays are till covered or strewn over with glacial erratics. Such are the features observed in traveling from Sandy Hill northeastward to Vaughns or Queensbury. These hillocks, mostly outliers of the Lower Silurian limestone, rise from a rather uniform level of 280 to 380 feet to elevations of from 25 to 50 feet above the surrounding surface. Their drift-covered surfaces indicate that the ice mass, which defined the limits and the breadth of the terraces on the north and west of the basin, on melting left its unassorted debris on the region. The clays in the lower places of this surface indicate the subsequent covering of the district by standing water.

As elsewhere observed, the clays in the floor of the trench of Wood creek northeastward of Fort Edward are ice worn.

Further indications of the overriding action of ice are found south of Fort Edward quite within the gorge of the Hudson at Summit station on the electric railway line. The annexed figure is intended to show the nature of the disturbed clays as seen shortly after the excavations for the line were made [fig. 19].

Similar disturbances in the drift deposit were described by Fitch as being visible when the Delaware & Hudson Railroad cuts were made south of Fort Edward. All the evidence points to the conclusion that after the deposition of clays over the Fort Edward district at a time when the ice front had retreated an unknown distance to the north, there was an advance of the ice probably as far south as the mouth of the Moses kill within the Hudson gorge.

Deposits in Argyle and Hartford. On the east of the Fort Edward district, the morainal terraces at North Argyle and Evansville have already been described. Below these in the valley of the Moses kill in the region of the swamp north of Evansville are bordering kames and gravel deposits also laid down in the presence of ice.

Clays begin to appear in the upper reaches of small valleys at about 320 feet, as in the branches of Big creek southwest of South Hartford. Below this level the clays cover wide tracts, particularly from 300 feet downward to the margin of the Wood creek channel. These clays are everywhere incised by the numerous small streams of the region.

Glens Falls delta of the Hudson. The ice dam across the mouth of the gorge of the Hudson at the base of Palmertown mountain has already been described in its effect on the course of that river and in its bearing on the glacial terraces of that region. When the ice finally melted away from the low grounds about Fort Edward normal river and lacustrine deposits began to make. The gravelly and sandy delta of the Hudson spreading from the base of the glacial terraces at the mouth of the Adirondack canyon outward to Sandy Hill and Fort Edward was untrammeled in its development by confining masses of ice unless it be on the north side of the Hudson in the region about the city of Glens Falls. This delta is approximately 350 feet in elevation, rising to 360 feet according to the map at the base of the 400 foot or

second lower terrace at the base of Palmertown mountain [*see* pl. 13]. The low escarpment which separates this lower delta plain from the broad 400 foot terrace is a striking cliff of gravels sweeping southward from the Glens Falls quadrangle to the Schuylerville quadrangle on the south. As will be shown later its base corresponds closely with the presumed level of a stage of the glacial lake which covered this district and wave action is to be suspected as determining the form of the terrace though an earlier ice contact slope may have given rise to its position. The topography bears every mark of having been produced by erosion.

The delta of this stage evidently extended as far east as Sandy Hill and perhaps much farther toward Fort Edward. The southern and eastern margin of the present delta plain have been determined by erosion accomplished during the lower and later stages of the waters in which the delta was deposited.

The Hudson in its eastward course from the portal of the Adirondack canyon lies mainly on the north side of the delta as does the Mohawk in relation to the delta extending from Schenectady to Albany. There is a narrow strip of delta sand west of Glens Falls but within a mile north of the town and the bank of the river there is little or no evidence of stream-borne waste. Had the stream at any time wandered into this marginal field of its delta before sinking its present channel the river would easily have fallen into the course of Half Way creek and so joined the Champlain drainage. It is to be suspected that, where streams flow along the northern margin of old deltas built into glacial lakes of meridianal valleys, their courses were determined by the natural tendency to diversion into the depression which would arise on that side of a delta through the retreat of an ice barrier. No satisfactory evidence of the presence of the ice on the north side of the Glens Falls delta at this stage has been observed. In fact the continued development of the deposit since it might outlast the presence of the ice, did such a condition exist at the commencement of the process, would tend to obliterate those evidences of the ice contact on which the proof of the existence of preglacial deltas must ever depend. Other postglacial changes

are seen on the surface of the delta in the sand dunes which have there developed.

Along the southeastern border of the delta the land drops off to a clayey terrace lying between 250 and 280 feet in elevation. It is well exhibited at Reynolds Corners [*see* pl. 13]. The slope from the 350 foot delta plain to this lower terrace from Fort Edward southward coincides closely with the boundary between the Calciferous-Trenton limestones and the Hudson river shales which lie on the east of them. But the immediate origin of the slope appears to be due to erosion taking place subsequent to the formation of the 350 foot delta. This lower terrace corresponds in position with a tilted water plane of a glacial lake whose outlet on the south, as is shown on plate 28, was in the

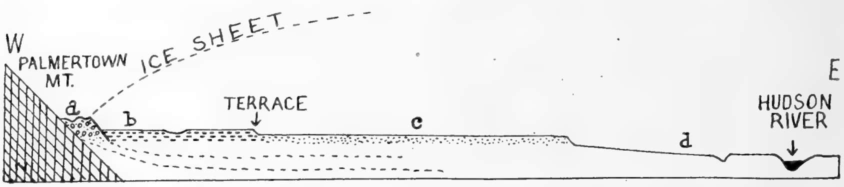


Fig. 20 Profile of the terraces and delta levels from the base of Palmertown mountain to the Hudson river. *a*, The glacial terrace; *b*, the broader terrace at 400 feet; *c*, the delta of the Hudson; *d*, the clay terrace, a part of the channel of the stream which flowed through the Coveville outlet

old channel back of Schuylerville which falls into the Hudson gorge at Coveville.

Below the level of this terrace is the old channel continuing the Hudson gorge by way of the Wood creek valley to Lake Champlain, the evident path of a river which as I shall hope to show later in this report drained a glacial lake in the Champlain valley into the Hudson gorge. East of this channel is a branch at a somewhat higher level perhaps earlier occupied by the same stream before that nearer Fort Edward was so deeply excavated.

The above diagram, figure 20, is intended to show by an east and west profile the successive terrace and delta levels of the Fort Edward district, down to the existing channel of the Hudson below the site of the old fort.

The effect of ice barriers and glacial lakes about the southeastern base of the Adirondacks is so well exhibited in the case of the Hudson river that the following digression is introduced

partly to summarize the evidence and correlate the delta deposits of this region.

The three deltas of the Adirondack Hudson. The Adirondack Hudson river has three deltas of late glacial age at the southeastern base of the mountains, one at Corinth, one at Gansevoort, and a third at the base of Palmertown mountain. The river flowing southward through the Precambrian rocks of the Adirondacks touches at Corinth on the northern end of a fingerlike projection of the Cambrian and lower Silurian strata let down by faulting within the walls of older rock, but instead of following this tract of newer rock southward to the open ground toward Ballston, the river now turns rather abruptly eastward across a broad tongue of the Precambrian rocks and emerges on the Fort Edward district through a deep gorge in the Adirondack *massif* just above Glens Falls.

When the ice sheet in its retreat had its front in this region, the pressure through the Champlain trough appears to have maintained a barrier of ice against the eastern wall of Palmertown mountain, thus preventing the escape of the river in that direction while the path southward from Corinth was open. Hence the river discharged its waters, laden with gravel and sand, through the broad valley followed by the Adirondack Railroad from Corinth southward. In the earlier stages of the melting of the ice from this valley a very high and massive kame terrace was built on the western margin of the ground held by the delta at the next stage of building.

These kames with their kettles here and there holding lakelets are very conspicuous for a mile or more south of the railroad station at Corinth. At the time the deposits were formed, ice must have occupied the valley below and have extended eastward perhaps in continuity with the sheet lying over the Fort Edward district.

The village of Corinth stands on the northern edge of the delta which has the form of a rather steeply inclined outwash fan flooring over the valley with its crest on the north overlooking the river. The present examination of the region was not carried beyond this point to determine to what extent the Hudson valley above Corinth was free from ice at the time the delta was formed.

As soon as the ice shrunk away from the eastern base of the mountains at and south of Palmertown mountain, a lower course was open to the river which now escaped along the eastern base of Palmertown mountain and flowed between the ice and the mountain wall till the ice front was reached, there spreading out the broad plains of gravel and sand near Gansevoort on the margin of the body of water in which the Albany clays were depositing. At this time the ice evidently stretched eastward across the upper Hudson valley at the southern margin of the Fort Edward district. The Gansevoort delta at present largely modified by the drifting

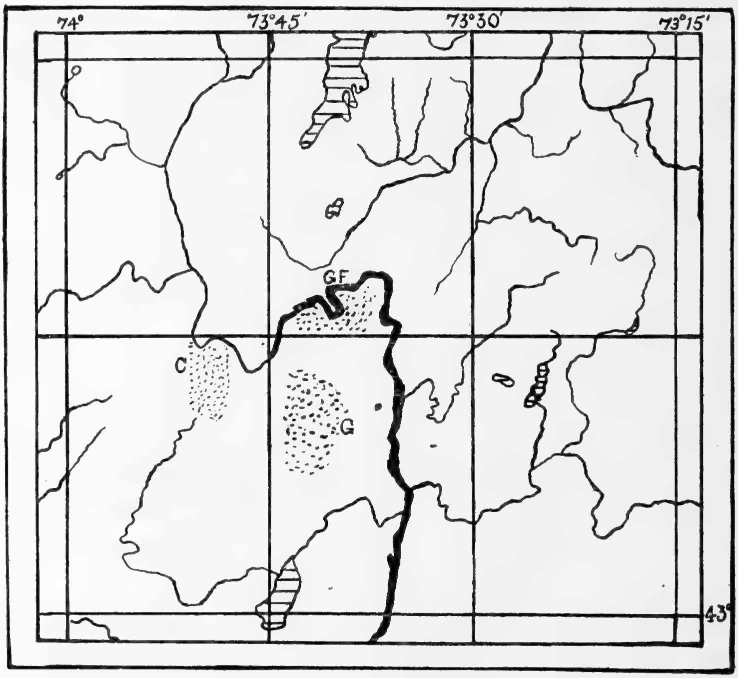


Fig. 21 Sketch map of the three deltas of the Adirondack-Hudson. C, the Corinth delta; G, delta near Gansevoort; GF, the Glens Falls delta

of its fine sands by the winds has its inner upper level at 325± feet above sea level. It forms a broad gently inclined fan without very definite outer margin, indicating that the water level of Lake Albany was somewhere between the 300 foot and 325 foot lines above the present sea level.

Along its northern margin the delta is broken by large kettle holes containing small lakelets showing the approximate position

of the water-eaten margin of the mass of ice which lay over the Fort Edward district at the latest stage in the delta construction.

It was probably at this stage that the terrace of coarse gravels lying at the base of Palmertown mountain was deposited. An intermediate stage is marked by the small terrace on the flank of the Hartman terrace lying on the north bank of the river just within the Adirondack gorge of the Hudson.

Afterward followed the several stages of broad terrace building described as margining the Fort Edward district on the west, ending in the delta which spreads forward from the mouth of the Adirondack gorge toward Glens Falls on the south side of the river. The ice front or at least the southern margin of the remnant which lay over the district may have lain along the northern bank of the Hudson from the gorge toward and beyond Glens Falls, preventing the delta from building on the north side of the present channel. As the ice shrank away from the delta along its front, the stream fell into the depression thus made and so found its way across the limestones and shales past Sandy Hill to the old gorge at Fort Edward, thus establishing the connection of the Adirondack-Hudson with the main channel.

Delta of the Mettawee river. The Mettawee river crosses the northeastern part of the Fort Ann quadrangle in Granville and Whitehall townships. In the western part of Granville the roughened plateau of eastern New York falls off to the lower levels of the town of Fort Ann within the clay-covered ground east of Wood creek. Clays cover the surface up to approximately the 300-foot contour line. Opposite the valley of the Mettawee, within the eastern plateau in the vicinity of West Granville, a gravelly and sandy delta of the Mettawee has a small development much less extensive than the deltas of the Batten kill and the Hoosic river farther south.

The head of this delta is about 320 feet in its present elevation above the sea, passing into terraces at North Granville which rise gradually up the valley and attain a level of 400 feet at Middle Granville. The delta slopes gently outward to the 300 foot contour north and south of West Granville and there gives way to the clays which mantle the lower grounds northward to Whitehall and southward into Hartford. It is safe to assume

that the water level marked by the delta lies between the 300 and the 320 foot contour lines.

The slight development of the Mettawee delta on the margin of the Hudson-Champlain valley as compared with the extended deltas of the streams of similar size today on the south appears explicable in the view that the deposit did not begin to form till the ice which covered the Fort Edward district melted out. It has been shown in the account of the Fort Edward district that there are strong reasons for believing the ice front lay for some time on the south of that district between Fort Edward and Schuylerville. Into the water body covering the clay grounds south of the ice front, the Hoosic, the Batten kill, and other streams farther south were building their deltas and continued so to do while the water was maintained at the level of the delta margins.

The Mettawee turning northward along the eastern margin of the delta has cut a deep trench into the underlying clays and now flows over the bed rock with low falls about 1½ miles below North Granville.

The delta of the Mettawee correlates with the inclined water plane of a glacial lake at the Coveville stage, as shown on plate 28.

Delta of the Poultney river at Fairhaven Vt. The Poultney and Castleton rivers join near Fairhaven Vt on a broad gravelly plain overlying glacial clays. This plain has an elevation of about 380 feet. It is inclosed, except for a pass on the west followed by the Rutland branch of the Delaware & Hudson Railroad and on the north by the valley through which the Poultney escapes, by high land, and thus appears not to have been a delta built on the margin of an open sheet of water as was the case with the deltas of the Mettawee and other streams on the south.

The delta of the Poultney lies between the more marked levels of the tilted water planes which converge on the outlets of a glacial lake below Fort Edward. It would appear therefore to have been made in a narrow valley opening westward on a glacial lake. Much more detailed work will be required in order to correlate satisfactorily these deposits on the Vermont side of Lake Champlain. The surface of the deposits at Fairhaven

lie only a few feet above the tilted level of the lake in which the Granville delta was made, and appear to be correlated fairly with the Coveville stage.

At Carver Falls, a terrace exists at practically the same level, but the reconnaissance of the district has not sufficed to determine any definite relation which this deposit bore to the retreating ice or to the lake which stages once existed over the lower ground in the region about Whitehall. It is to be observed that at Dresden Center on the west side of Lake Champlain and nearly due west from Carver Falls clays occur from the lake shore up to about the 380 foot line.

Partial summary. Within a radius of about 5 miles on the east, north and west of Glens Falls, there are deposits made in the presence of lingering ice. These deposits form terraces of varying width, with their summit planes at altitudes varying from about 440 to over 500 feet in elevation. These terraces appear to have risen above the level of the clay-depositing waters which later covered the lower roughened plain of the Fort Edward district.

The low rounded clayey hills along the line of Wood creek between Fort Edward and Fort Ann are composed of glacial clays evidently overrun by an advance of the ice and strewn with small boulders. Following this there is evidence of the extension of the Hudson delta at the 350 foot level spreading sands as far east as Sandy Hill at lower levels beneath the water surface. Clays made over the higher ground on the east in Argyle nearly to the level of the delta. Still later there are evidences of powerful currents passing southward through the district into the gorge of the Hudson. In a later chapter it is thought the explanation of these phenomena is found in the series of outlets for a glacial lake which extended from the southern border of the Fort Edward district northward through the mountain passes into and over the Champlain valley to the ice front stretching between the Green mountains and the Adirondacks.

Chapter 5

RETREAT OF THE ICE SHEET IN THE CHAMPLAIN VALLEY

The retreat of the ice sheet in the Champlain valley has been largely obscured by the extensive modification of deposits at low levels through the action of waves and running water. In only one portion of the field was much attention paid in the course of the present investigation to the ice retreat and at no point in the length of the lake am I at present able to state the precise line of ice frontage across the lake valley. The following notes on such localities as chanced to be examined in the course of the search for water levels by no means give a complete account of the recession.

As will be noted from allusions in these descriptions and from the conclusions to which I have been led, a glacial lake appears to have extended northward in the valley pari passu with the retreat of the ice front. Still earlier as remarked by several observers there were probably lakes held in along the margin of the ice sheet both on the Adirondack and Green mountain sides. Taylor has given the name of Lake Adirondack to such a body of water whose traces he recognized in the region back of Plattsburg. Probably other similar lakes existed in the upper basins of the Winooski and Lamoille rivers in Vermont [*see* pl. 27]. Some or all of these marginal lakes must have later become confluent with or drained into the greater lake which was held in by the ice sheet while its front stretched across the valley from the Green mountains to the Adirondacks.

Mr Baldwin has supposed this front to have been concave northward on account of the melting effect of the water which bathed it. This need not necessarily have been the case, however, provided the rate of the forward movement during the retreat counterbalanced or exceeded at times the rate of melting. My studies on the Mooers quadrangle have led me to an opinion just the opposite of that expressed by Mr Baldwin. All the phenomena in that area show that the ice was "alive" even at this late time in the retreat. It built frontal moraines; it maintained its frontage for some time along the margin of

remarkable spillways despite the favorable conditions for backward melting owing to the presence of water warmed by flowing over bared rock; it had in that area a northwest-southeast alinement and in consequence of its power to press high up on the Adirondack slopes must have been able to maintain a more or less lobular frontage across the Champlain valley.

Mr Gilbert, it should be stated, has described to me deposits on the northern side of Covey hill in Canada which he interpreted as indicating the return of the ice sheet after it had disappeared from that vicinity. The evidence consists of what appears to be a patch of frontal moraine between two marine beaches.

In a very suggestive paper on this region Mr Upham has expressed the belief that in the very latest stage of the ice retreat from the St Lawrence valley, the ice stood in such a position still as to debar the sea from entering the Champlain valley but to permit the confluence of the glacial dammed waters in that valley with those over the upper St Lawrence and Ontario valleys. I am not able at present to affirm or deny the pertinency of this view.

The following details concerning glacial deposits serve to show the general character of the latest stage of ice action in the State.

Dresden gravels. A conspicuous deposit of glacial gravels occurs in the southern constricted portion of Lake Champlain at Dresden station on the Delaware & Hudson Railroad, and extends southward toward Chubb's Dock. The deposit is also exposed at Cold Spring on the Vermont side, where the gravels are screened and shipped in canal boats for use as road-metal.

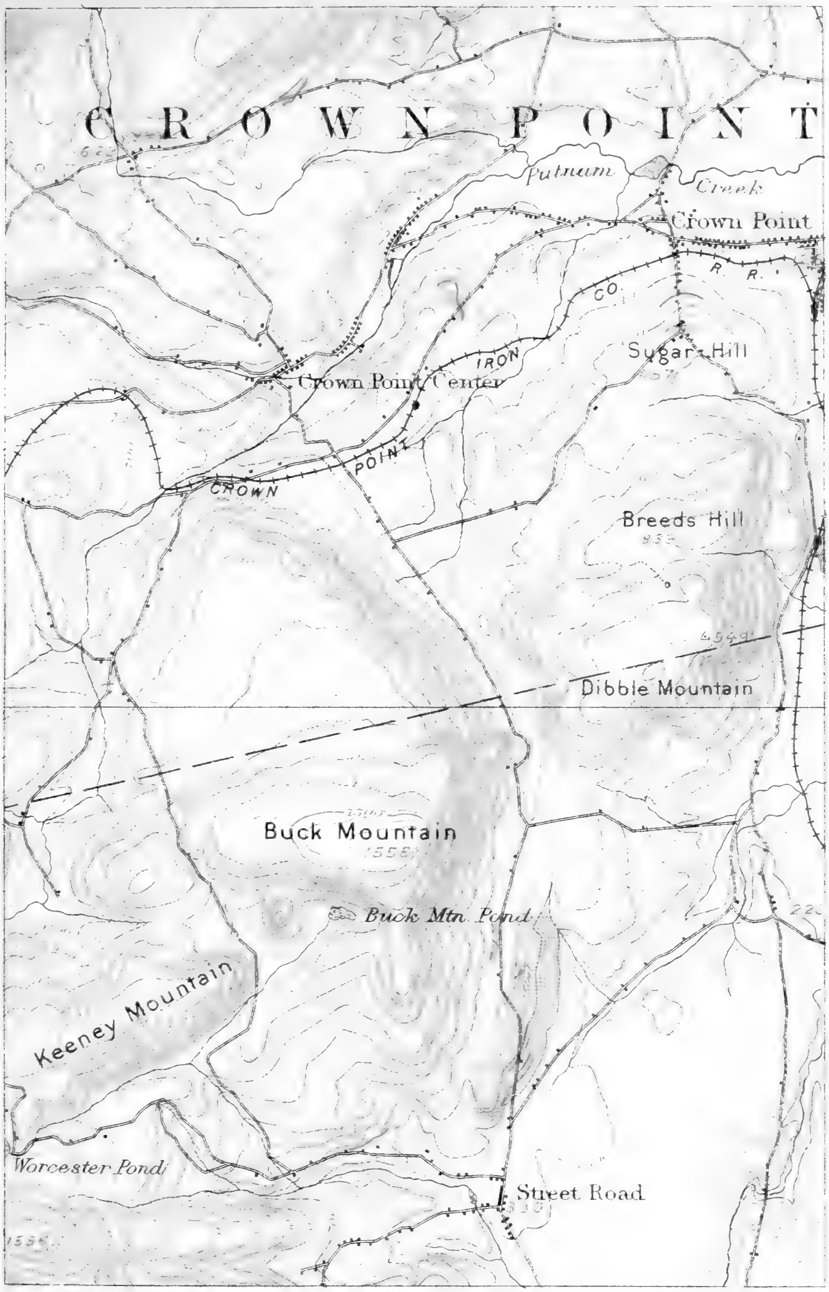
The gravels show alternations from very fine to relatively coarse sediments with a stratification characteristic of outwash deposits. The materials in the terrace at Dresden become perceptibly finer southward, indicating that at the time of their deposition the drainage from the ice was southward through the Wood creek channel into the Hudson valley.

The coarse gravels which occur throughout the section indicate that if standing water existed at the time of their deposition, its surface was much below the level of that in which the subse-

quently formed clays were laid down in this district. Any great depth of water would have made it difficult for a current either in the ice or outside of it to transport such coarse materials at the bottom. From Dresden southward to Chubb's Dock, the so called Champlain clays rest on the uneven and often kamelike surface of these older gravels and sands.

Such amassments of gravel have already been noted in the Hudson valley occupying a like subjacent position to the Albany clays, as at North Albany and in numerous sections from north of Cohoes to the point where the stream draining Round lake falls into the Hudson. The deposits are evidently glacier margin deposits associated with the final melting out of the ice. If the structures of these gravel deposits at North Albany and Dresden have been correctly interpreted, it would seem as if for a time at least the land must have been higher than it was during the lake stages in which clays were deposited and high enough in relation to the southern Hudson valley to permit a rather free run off of the glacio-natant waters. The isolated facts cited from the talus at the southern base of Skene mountain at Whitehall and the similar phenomena east of Saratoga lake [*see* p. 136] strengthen this conclusion—that changes of level were taking place during the retreat of the ice sheet. This particular movement appears locally to have affected lands lying above sea level. Its recognition carries with it, in view also of the marine deposits which followed, the assumption that following the disappearance of the ice from this portion of the valley a reversed movement set in by which the land was lowered on the north relatively to the southern part of the State so as to produce an uplifted barrier in that direction capable of retaining the waters which formed the lakes whose records are so clearly shown in the succeeding deposits of clays and marginal sand deltas. It must be borne in mind, however, that these earlier movements preceding the clearer records of the glacial lakes and the marine invasion depend on scattered and fragmentary evidence which further study of the district may prove in a better light to be capable of a different interpretation.

Street Road terrace [Ticonderoga quadrangle, pl. 15]. North of Street Road and at the eastern base of Buck mountain there



THE STREET ROAD LATERAL MORAINE TERRACE

And some of the clearer shore-lines about Crown Point

Scale $\frac{1}{62500}$

1 ½ 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Lateral terrace	Morainic deposit.	Eskerlet.	Kettle-hole.	Wave-lines.

is a high lateral moraine terrace locally known as Sawyer hill, whose surface is contoured by the 540 foot line. Buck mountain rises in a steep wall to a hight of over 1000 feet above the level of this deposit. An excavation made at the southern lobe of the deposit showed it to be stratified with a foreset structure dipping south. The materials are gravelly. In about the middle of the terrace to the west of the point where the highway from Street Road to Crown Point reaches the summit there is a large and well defined kettle hole. Farther north evidences of deposition in the presence of ice continue to appear; and in the pass between the outlying tectonic block of Dibble mountain and the eastern face of Buck mountain (see the Ticonderoga sheet for details of topography), there is a deep depression marked with kames and abundant indications of the presence of ice in the deposition of the materials whether by water or ice alone. The bottom of this pass according to the contours of the map is at least 80 feet lower than the surface of the terrace on the south. The eastern face of this terrace is a steep slope ribbed by gentle wave lines, the highest of which is at about 500 feet elevation. The terrace appears to have been built by waters discharging through the Buck mountain pass from the depression about Crown Point north of this mountain and to have been bordered by the ice sheet on its eastern flank if ice did not also lie in the depression on the north of it. There was evidently a small glacial lake held in south of it in the valley of the small stream which drains Buck mountain and Worcester ponds. There are notable sand deltas on this stream at even higher levels than the Street Road terrace. The precise position of the ice front across the valley of Lake Champlain at this time has not been determined but it presumably lay to the south of Street Road. Later the front appears to have lain locally on the north side of Dibble mountain, a tongue pressed forward into the pass before mentioned, and east of the mountain the front presumably crossed the axis of the valley somewhat farther south.

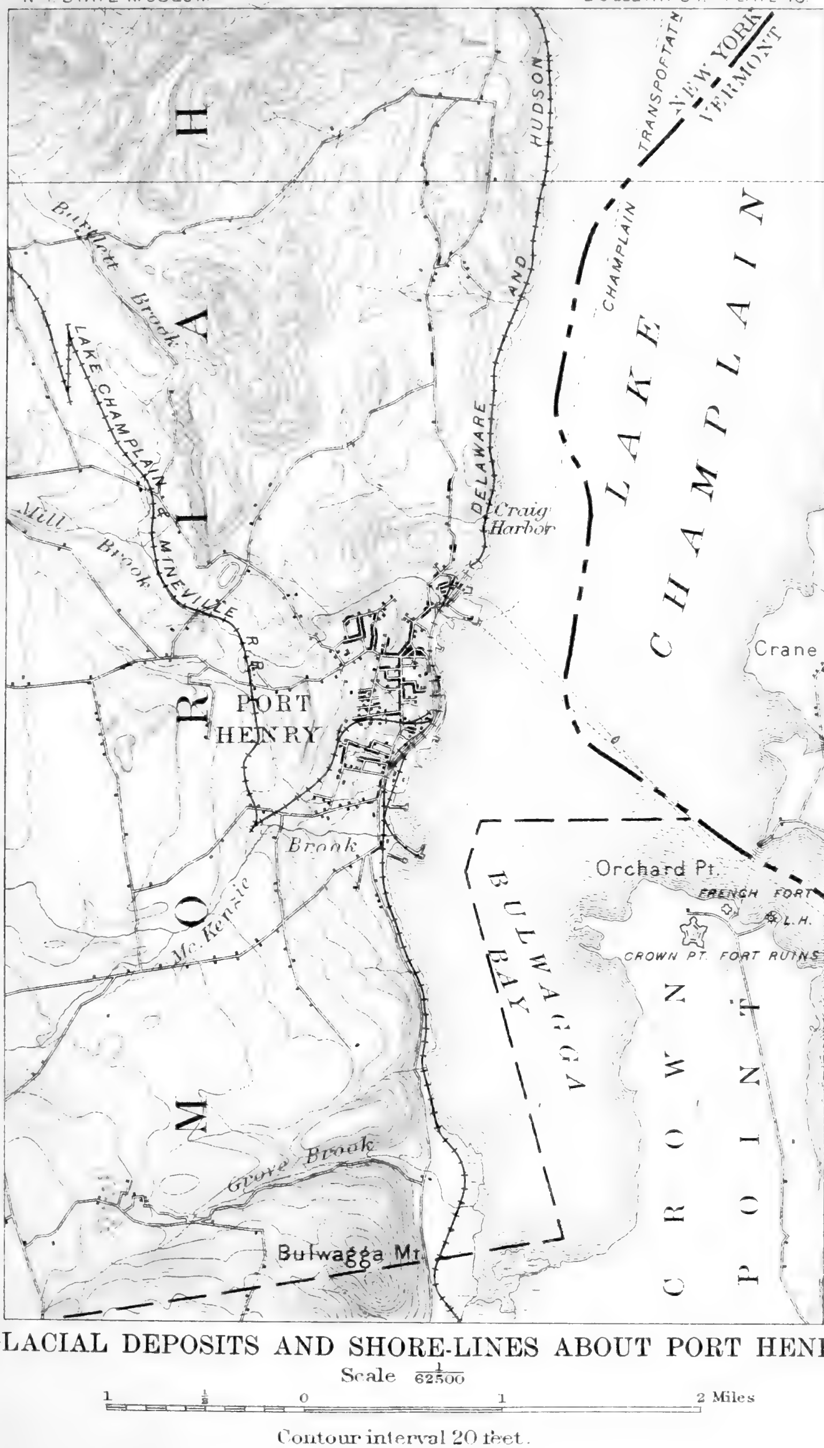
After the ice disappeared from this vicinity the open waters in the Champlain valley appear not to have stood higher than the wave marks on the side of the terrace, viz 500 feet, for the kame kettle on the top of the terrace shows no signs of having been

filled by the wash which would have been drifted into it by wave action at its own level.

Possible local glacier at Port Henry. The presence or absence of local glaciers in the Adirondacks and neighboring mountains of New England continues to be a mooted question. Several writers have reported what has appeared to be evidence of local glaciation following the disappearance of the Laurentide glacier from the Adirondack mountains. Till detailed mapping of the area shall have been undertaken the question is likely to remain more or less open. The importance of the question can not be gainsaid in an investigation of the water levels which have existed in the Champlain valley in view of the possibility of ice dams which may thus have been introduced and maintained after the withdrawal of the Laurentide ice. A few observations of the writer during the present investigation of the foot region of the Adirondacks have prepared him to find that local glaciers may have extended near enough to sea level in the time of depression to have interfered with the development of normal shore phenomena, but much more careful work is required before it can be asserted that the phenomena already seen prove the existence of local glaciers.

The question of local glaciers has been raised in the present survey mainly by the abnormal striation and the lateral moraine terrace at Port Henry and by the faint traces of a late north-south striation about the northern border of the Adirondacks where the earlier Laurentide ice in diverging lines of flowage moved up the St Lawrence valley on the north of the Adirondacks and up the Champlain valley on the east of this obstruction to its flow.

Port Henry lies on the western shore of Lake Champlain at the foot of a broad depression in the high hills which confront the lake for several miles on the north and south. The floor of this depression rises westward and expands north and south for a few miles. Still farther westward the ground rises more rapidly into the highest part of the Adirondacks. Along the shores of the lake north and south of this depression roches moutonnées with rounded northern backs and clifflike southern fronts together with northsouth striation attest the southward



GLACIAL DEPOSITS AND SHORE-LINES ABOUT PORT HENRY

Scale $\frac{1}{62500}$

1 ½ 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Lateral moraine terrace.	Glacial striae.	Frontal (?) moraine.	Shore-line.	Gravel terrace.	Sandy deposit.

flow of the Laurentide stream of ice through the Champlain valley. In the village of Port Henry, near the Lake Champlain and Mineville Railroad station, well developed nearly eastwest glacial striae indicate a movement later than the main glaciation and normal to it. The striation referred to is n. 68° e. Again ½ mile south of McKenzie brook along the street between the 300 and 500 foot contour lines, glacial striae occur having a more nearly east and west (n. 83° e.) direction. In the southwestern corner of the Port Henry quadrangle, just south of the red schoolhouse, glacial striae with a course n. 43° e. cover a well worn ledge. Beginning on the north again in the bed of Mill brook at a point north of the road crossing the stream about ¼ mile southwest of the race track, there are glacial striae running n. 80° w. South of the road crossing, striae of the northsouth set occur. These localities are shown on the accompanying map [pl. 16].

Northwest of Port Henry at a distance of 1 mile begins a spur of foothills at the western base of which runs Bartlett brook, the north branch of Mill brook. The western slope of this spur carries a well defined lateral moraine terrace which projects beyond the rock hill on the level ground west of the race track. From this point, the surface of the terrace rises rapidly to the northward for about a mile beyond which no attempt has been made as yet to trace the deposit. The terrace can be plainly seen from the Mineville Railroad near the upper switch back. The presence of this terrace in this position seems to indicate clearly that the margin of an ice mass rested against this western slope of the spur. One mile south of the southern end of this deposit, south of the valley of Mill brook and the north branch of McKenzie brook, the land rises to the 800 foot contour line and is crested with a recognizable hummocky moraine.

Three hypotheses suggest themselves at once in the explanation of the peculiar striation of this area. First, the abnormal striae were produced by the westward protrusion of the margin of the Champlain lobe at a time when it was mainly confined to the walls of the lake valley and pressed against though it did not overtop the foothills. Wherever a low place in the valley wall

presented itself, it might be expected that the ice would deploy into it. Second, these local striae are due to a branch of the main Champlain lobe which passed southward through the mountain valleys on the west and rejoined the main lobe at Port Henry. Third, the striae are due to a local glacier or to small glaciers coming at least to within 60 feet of the present lake level from snow fields in the high area on the west, whose culminating point, Mt Marcy, is 24 miles distant in a west by north direction.

The position and nature of the till deposits of morainal character shown on the map are explicable by the second and third hypotheses. The fact that the eastwest striae extend quite down to present lake level favors the first hypothesis on account of the difficult assumption that a local glacier would push its front to so low a level after the main ice had retreated from this latitude. On the other hand the striae near the present lake shore come to the shore so abruptly as to give no support to the first hypothesis. I was not able to make out from the details of the few striae observed whether the ice movement indicated by them was toward or away from the present lake. In the case of the ledge near the red schoolhouse southwest of Port Henry there are crescentic flakes in the gneissoid rock with the horns pointing to the northeast. I have seen similarly fractured pieces removed in which the horns of the crescent pointed in the direction in which the ice was moving. If that be true here it is a point in favor of local glaciation.

In the Mill brook locality, the glaciated ledge of the abnormal set was overlain by a gravelly boulder clay containing fragments of Potsdam sandstone, gneisses and limestones.

Bulwagga mountain comes to the lake front with a bold escarpment and, blocklike, rises between the depressed region of Port Henry and the similar area of Crown Point. In this latter side valley glacial striae, n. 42° e., were observed just south of the village on the north slope of Sugar hill. On the road from Crown Point Centre to Coot hill, glacial striae may be seen running n. 48° e.

Yet farther south of the west side of the lake in the vicinity of Ticonderoga, the striae range from n. 13° e. to n. 33° e., dis-

Plate 17

Frontal moraine ridges north of the Altona spillway between Altona and Sciota. Looking northeast

playing the draft of the ice in these localities into the Lake George passage. All the striae from Bulwagga mountain southward exhibit this southwesterly trend at a considerable angle with the axis of the main valley showing that the axis of the glacial line of flowage lay to the east of the present shore of Lake Champlain; but nowhere have I seen in this southern area within 800 feet above the lake such anomalous variations from the southward and southwestward striation as those which occur in the Port Henry area.

The other cases of glacial striation which fail to agree with that which is normal for the region are found in the meridional scores which occur in Clinton county, N. Y., in the town of Mooers and farther west between Cannon Corners and Clinton Mills.

A ledge of Potsdam sandstone at the sharp bend in the Great Chazy river between Thorn's village and Mooers Forks carries separated and rather faint striae running n. 19° w. The adjacent bank of the river is for the first 10 feet above the water composed of sandy till, largely Potsdam drift, which must originally have covered the rock here referred to. The neighboring normal striation is shown in a near-by ledge farther down stream to be n. 36° e.

A ledge on the Perry's Mills road 2 miles west of that village exhibits faint striae n. 16° w. Striae running n. 10° e. occur in the ditch on the south side of the Rutland Railroad, 1½ miles west by south from the bridge over the Great Chazy. Both of these cases depart from the maximum flowage direction which would be expected for the northeast corner of the Mooers quadrangle from what is known of the more abundant striation immediately southwest [*see* geologic map of the Mooers quadrangle, pl. 29].

A little less than 3 miles north from Ellenburg depot and at a point ½ mile south of the English river on the road to Cannon Corners, bare ledges of Potsdam in the road show abundant rather widely spaced striae whose direction is n. 10° w. The normal direction for this region according to observations on the northwestern corner of the Mooers quadrangle would lie between n. 46° e. and n. 61° e. The divergence between the normal

thickly set striae and the discrete evidently later glaciation is so great that it hardly appears probable that the two sets pertain to the movements of the same glacier even when account is taken of divergent flowage in a retreating ice lobe. In the case of the abnormal striation in the northeastern corner of the Mooers quadrangle, it is conceivable that the ice when it had become so thin as to be diverted by the Covey hill ridge, on the east of this elevated district turned more sharply than before into the Champlain valley; but the striae north of Ellenburg depot can not be so explained. The cases above cited recall the later separate striae described by Chalmers as occurring south of the St Lawrence near the international boundary opposite Vermont and New Hampshire and which have been interpreted by him as produced by local glaciers descending the mountains along the frontier of New England into Quebec. As yet no evidence of associated frontal moraines nor the northward transportation of erratics which would corroborate this view has been detected along the northern border of New York. Much further work in this region will be required to demonstrate the precise nature of these anomalous striae.

Southern slope of Rand hill and Dannemora mountain. A relatively late stage of frontal deposits is well developed along the southern slope of Rand hill and Dannemora mountain where the drift is very thick particularly opposite the notches opening northward through the mountain. The ice pressing against the northern side of these elevations appears to have pressed through the valleys and built up a shelving terrace of interstratified till and washed gravels on which the tongues of the glacier at times rested. From the evidence of heavy deltas between Dannemora and Lake Champlain there appears to have been standing water in this embayment at levels above that of the main body of water which later lay in front of the ice over the Champlain valley proper. Such is the delta at Cadyville on the Saranac.

Moraines north, east and west of Rand hill. Rand hill as shown in the report on the Mooers area [N. Y. State Mus. Bul. 83] is encircled with lines of retreatal moraine on the east, north and west [*see* pl. 17]. These moraines with the exception of a lower group to be more particularly mentioned show no signs of wave action or of attendant outwash plains constructed in

Plate 18

View in the Altona "flat rock" spillway, about ¾-mile northwest of "Dead Sea"; elevation 750 feet, looking s. 26° w.

standing water. Between the lowest of this group of frontal deposits on the north and the higher ones there intervenes the remarkable "flat rock" areas or spillways of Altona extending into the region northwestward as far as the international boundary at Covey hill, Canada.

Flat Rock spillways [*see* pl. 18]. These bared surfaces of the Potsdam sandstone mark the path of a torrential discharge of water held on the northern slope of the mountains along a line from the notch at "the Gulf" [*see* pl. 25] on the international boundary line to a point west of the village of West Chazy, a distance of about 19 miles. It is necessary to suppose that the ice front lay along the lower side of this spillway belt, which thus becomes quite as definite as a frontal moraine in the fixation of the position of the ice at this time. This line of evidence is confirmed by the occurrence of strong frontal deposits along the lower margin of the spillway zone near West Chazy at "Cobblestone hill" and northward [*see* geologic map of the Mooers quadrangle, pl. 29].

More important than all this is the evidence afforded by the torrential action concerning the hight of the standing water then in the valley of Lake Champlain. The lower margin of the stripped bed rock near West Chazy descends nearly to the 620 foot contour line; its upper limit in the district is approximately 900 feet; farther north its upper limit is as high as 910[1] feet, and in the Gulf there is a water pool [*see* pl. 19] at the base of an abandoned waterfall at 810[1] feet, and there is a lower lakelet in a chasm at 645[1] feet [*see* pl. 20]. These lakelets would not have been produced by a fall of water into this channel when it was deeply submerged. There are evidences of water standing at some episode in this phase east of the Gulf[2] at a level between

[1] These elevations are from Mr Gilbert's notes, but have been taken independently by myself.

[2] There is a brief account of the Gulf given by Ebenezer Emmons in the *Geology of the Second District.* [Clinton County, p.309–10, 1842] He reports the small lake at the bottom as "said to be 150 feet deep." He also states that "To account for the present condition of this rock, we have therefore to go back to a period when some current swept through this gorge with great force and power; for by no other means could the materials, which once filled the space between the present walls of the gulf, be removed." This is the first notice I believe of this spillway in scientific literature.

the levels of the two lakelets. An ice barrier extending to the north and west of Covey hill caused the waters along its front to escape through the pass on the south side of the hill. When that ice barrier withdrew from the northern slope of the hill it would have at once allowed the waters to take a lower channel around the northern slope of the hill and at the same time it would have removed the barrier which on the east of the hill retained the glacial lake at its high level. It can not be supposed therefore that any part of the Gulf was excavated after the ice sheet withdrew from the northern side of Covey hill. The occurrence of the high beaches on the northwest corner of the Mooers quadrangle at a level above the lower lake in the Gulf chasm, together with the line of beaches along the northern border of the Altona flat rocks—there lying above the lower limit of these rocks—makes it reasonable to suppose that after the scouring of the flat rock spillways had been well begun there was, at least at the northern end of the Champlain valley, a local relative rise of the water level as the ice receded and this would be a consequence of the downsinking of the land in this northern region. An uplift of the country about the lower Hudson would have accomplished the same result. That there was a local change of the first description is probable since as will be brought out more fully later, the shore lines in the Champlain district are more steeply inclined to the south than are the earlier water levels between New York and Albany. The reversed direction of tilting of the land to the south which has since taken place would produce the observed discordance if the land were tilted more and more to the north while the glacial lake advanced northward in the face of the retreating ice sheet.

Evidence from the northern face of Covey hill [*see* pl. 25]. As is shown in more detail in the report on the Mooers quadrangle, the northern face of Covey hill is a critical field for the study of water levels in the upper St Lawrence valley. Mr Gilbert appears to have been the first to perceive this point and was I believe the first to make critical though unpublished observations on this interesting locality. Covey hill and the Gulf are localities at which most lines of evidence presented in this paper come to a focus; hence the various features which are there presented will be found often under separate headings in this report.

Plate 19

View from north end of the gulf at Covey hill, looking east over the upper lakelet at 810 foot level. View in Canada

As regards the position of the ice front on the northern flank of the hill, it should be stated that as noted by Mr Gilbert the highest well defined and clearly demonstrable beach along this line is at 450 feet above sea level. But above this beach occurs a succession of rude terraces with coarse and often rather angular blocks from just above the 450 foot line to about 570 feet. Some of these are lines strikingly level for long distances; yet other parts of this system are inclined. All of them and particularly the highest show considerable cutting into the till cover of the hill. A till cliff is conspicuous at a number of localities on the north side of Covey hill near the 570 foot level according to my aneroid readings. Waterworn pebbles and characteristic beach wall structure are apparently absent. Mr Gilbert according to his notes in his search for beaches ruled all these higher lines out, if I understand his notes correctly, because of their lack of horizontality. Prof. A. P. Coleman who examined them in my company in 1903 hesitated at the time to pronounce them beaches. They lie for the most part in the zone of certain high and coarse beaches of angular and shingly debris which can be traced to the southeastward on the northern part of the Mooers quadrangle. The deposits deserve further study with careful leveling and mapping. If not due to powerful waves these terraces seem to me to demand powerful currents acting in the manner of the streams which Mr Gilbert and later Professor Fairchild have traced along the ice front in central New York between Syracuse and Rome. Such stream action between the ice front and the slope of the hill would cut effectively and make a part of the stream bed in the till with one bank of that material, and the other half of the bed might be formed by the ice with the bank on that side also of ice. It is to be expected that, as soon as the ice withdrew somewhat from the northern face of the upper part of Covey hill, the heavy discharge of waters which had taken place through the Gulf would have been diverted to the north side of the hill at a lower level. Farther south on the Champlain side there was a glacial lake with constantly lowering stages into which these torrential spillway levels would merge. Such is the interpretation which I have placed on these terraces above the marine limit of 450 feet on the northern flank of Covey hill.

Further consideration of the changes of the ice front and the water levels at this stage are deferred to the chapter on the glacial lake which then overlay the Champlain valley [*see* p. 168].

Summary of retreat of ice in Champlain valley. Less evidence of the position of the ice front from time to time is found than is the case in the Hudson valley. This paucity of evidence is partly due to the extensive deposits of clay and sand found up to elevations of 400 and in certain localities up to 700 feet along the slopes or in the embayments of the Adirondacks and the Green mountains. It is also partly due to the fact that there appears for a portion of the retreat at least to have been a lake lying over the district with conditions unfavorable to the formation of pronounced frontal deposits. Certainly no clear frontal moraines have as yet been traced across the Champlain valley floor.

Small glacial lakes began to appear along the margins of the ice sheet as soon as it had shrunk to the dimensions of a mass merely filling the valley. In the numerous embayments on the western side of the valley, local bodies of water received delta-building streams from the back country.[1] The drainage of these waters was southward along the ice margin as shown by the southward building of the terrace at Street Road.

The question is raised whether or not a local glacier entered Lake Champlain at Port Henry, a point east of Mt Marcy. This and other localities of aberrant striation require further study in the field.

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[1] See paper by Frank Taylor on Lake Adirondack in bibliography appended to this report.

View along the boundary line between the United States and Canada where that line crosses the gulf; looking east

Chapter 6

VALLEYS OF LAKE GEORGE AND WOOD CREEK

The Champlain and Hudson valleys are connected by three narrow defiles beginning on the west with that of Lake George; next east comes that of the southern end of Lake Champlain via South Bay; then that of the Wood creek depression. These depressions, evidently preglacial, have been more or less modified by glacial erosion and deposition. For a time after the ice disappeared from these defiles, water appears to have stood over all but the highest of the cols (Harrisina hollow), on the eastern base of French mountain at the southern end of Lake George.

Lake George. The narrow valley occupied by Lake George is heavily choked with glacial drift at the southern end. The deposits from the ruins of old Fort William Henry southward along the old military road past Bloody pond bespeak deposition in front of a mass of ice filling the lake valley. Subsequent waters appear not to have risen as high as Bloody pond, a kettle hole in the drift, at an elevation of nearly 570 feet above sea level. The more open pass at the east base of French mountain appears to have been the line of the main preglacial valley. This pass is called Harrisina hollow on Fitch's map of 1850. There are here two apparently water-swept passages one at 393, the other at 349 feet in elevation.

Professor Kemp has called attention to the islands in Lake George as indications of an old divide, from which he infers that a stream once flowed north in the northern part of the lake and one south in the southern part, glacial deposition at both ends having brought about the existing ponding of the waters.

In the diagram, plate 28, it will be seen that the upper stages of glacial waters in this area following the retreat of the ice entered the northern part of the lake but the Harrisina channels could not have controlled the hight of any but those preglacial lakes which may have existed in the Lake George valley prior to the melting out of the ice from its northern end, for the reason that lower passes exist to the east in the Whitehall district.

No detailed examination of the valley was made in the present survey either for the history of the ice retreat or for shore lines.

Wood creek valley. The singular trench from Fort Edward to Fort Ann, alluded to on page 77, forming an extension of the Hudson river main trough has already been described. At its northern end it is continued by the valley of Wood creek into union with the Champlain valley at Whitehall. The drainage in both these swampy valleys is now northward into Lake Champlain.

Asa Fitch[1] ascertained, at the time of the construction of the Champlain canal through the Wood creek valley, a number of details concerning this swampy tract which are here stated in his words.

On excavating the Champlain canal, it was found that all along the valley of Wood creek, at about 6 feet below the surface was a layer made up of leaves, nuts, sticks, and logs, from whence springs of clear water were everywhere issuing. The nuts were plainly butternuts and beechnuts. Ash and other logs, quite sound, occurred, but no pine. Pine was originally abundant on the uplands each side of this stream, but none grew down in its valley. The trees, in most instances, it was plain to see, had their tops towards the south, that is, upstream. Below this layer of vegetable matter was a stratum of tough blue clay; above it was sand and loam, and in excavating for the bed of the canal lock 11 feet beneath the surface, the trunk of a black ashtree 2 feet in diameter, and somewhat decayed, was come upon.

A most important fact in this statement (continues Fitch) is that *these buried trees were mostly found with their tops towards the south, showing that when they were lodged here, the current was running in a direction the reverse of what it now does.*

One mile north of Fort Ann, Wood creek enters the highland region bounding the Fort Edward plains on the east, there plunging into a narrow gorge to pass into a constantly widening valley to Whitehall. This valley is of preglacial date at least with reference to the last ice advance but whether of Prepleistocene date in its restricted portion near Fort Ann is not now definitely known. Through it at Fort Ann the ice swept from the northeast as the striae south of Battle hill indicate.

Throughout the extent of this valley the clays which appear in Hartford and Argyle as well as in the low ground about

[1] A Historical, Topographical and Agricultural Survey of the County of Washington. Assembly no. 175, 1850. p.879–80.

Kanesville appear clinging to the sides of the valley in protected coves as high as the 240 foot contour in the vicinity of Comstock and westward. It is evident that these clays have been extensively eroded. In the stream valleys this removal may be attributed to the streams now flowing in them but in numerous cases along the sides of Wood creek valley the removal of the clays has been accomplished in a manner unaccounted for by stream action. These coves are repeated on the western shore of the southwest arm of Lake Champlain in the same series of deposits. The best explanation of them which I have arrived at attributes them to the sliding out of the clays in the manner of the land slips described by the late Dr G. M. Dawson[1] on the clay lands bordering the St Lawrence.

The occurrence of the coves on the western sides of valleys is in part explained by the sweeping away of clays by ice action along the eastern wall of the same valleys against which the ice sheet must have pressed with greater force. This admission of the greater age of the clays is in line with the eroded forms which the deposits assume from Kanesville southward to and below Fort Edward in the axis of the long trough before described.

Northward extension of clays into Champlain valley. The clays of the Wood creek valley, seen in Whitehall and about the northern base of Skene mountain are traceable into the Champlain valley proper. At Dresden Center the clays rise to 360 feet at least above sea level. Bodies of the clay occur in all the recesses of the narrow river valley or southern part of the lake as far north as Ticonderoga, where they are found as high as 400 feet above sea level.

No marine shells have so far been produced from these clays in this southern part of the Champlain valley or southward over the Fort Edward district. Numerous small and irregularly formed concretions are seen in the clays, and are sometimes reported by the inexpert as shells.

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[1] Geol. Soc. Am. Bul. 1899. 10:484–90. Remarkable Landslip in Portneuf County, Ontario.

Chapter 7

DELTAS AND SHORE LINES OF THE CHAMPLAIN VALLEY

The deltas of the Champlain valley have been studied by the Vermont geologists and later by Taylor, G. F. Wright, Baldwin and Upham. The shore line phenomena of the New York side particularly have received mention in the literature. Mr Gilbert in his unpublished notes and Cushing in his report on local geology appear to be the first to recognize their distinctness particularly in the northern part of the area where the valley is wider and waves either of the sea or of a glacial lake would have had a greater fetch than in the southern constricted portion of the lake.

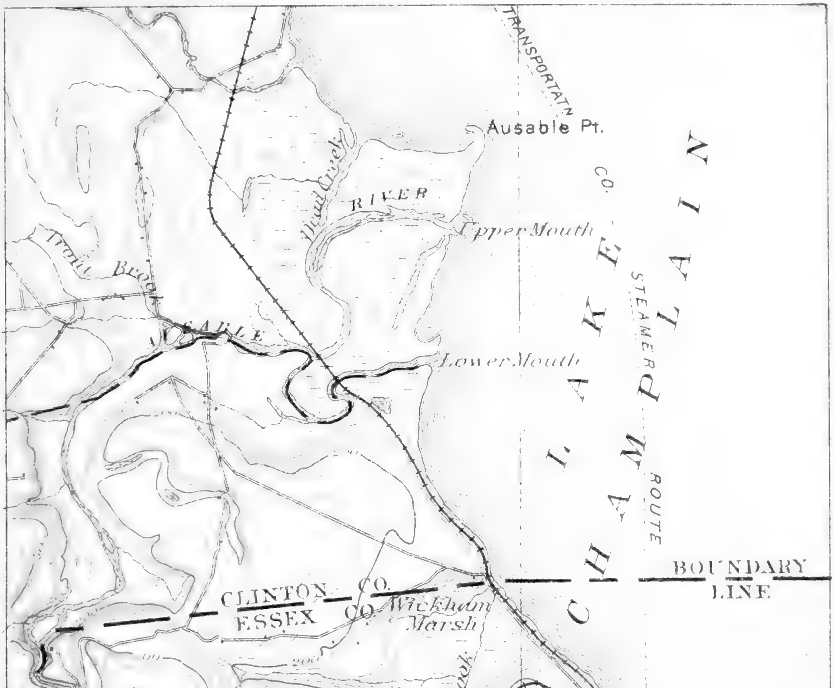
From near Ticonderoga something like beaches begin to become recognizable in favorable situations and gradually increase in size and distinctness toward the northern part of the State till within a few miles of the international boundary where they become here and there striking objects.

Space can be found for the description of types of these deposits only and then mainly the highest occurrences seen.

Parallel roads on East Bouquet mountain. Immediately west of Bouquet station on the Willsboro quadrangle rises East Bouquet mountain, a rounded hill attaining an elevation of 1225 feet. On the northeast slopes of this hill signs of wave action are traceable about halfway to the top. As nearly as I could estimate my position on the uppermost of these marks by the contour lines of the map, the highest of these wave lines is at 570 feet. The plane of tilting between the highest wave marks on Trembleau mountain and the Street Road highest beach cuts this hill at 560 feet, which is presumably a better reading than 570 feet [*see* pl. 28 and explanation].

Port Douglas beach ridge. On the Willsboro quadrangle, south of Trembleau mountain, a foothill of the Mt Bigelow mass is formed by a relatively thick drift deposit in the form of a ridge overlooking Corlear bay. The crest of this ridge, contoured to 540 feet on the United States Geological Survey map, is wave heaped with subangular cobbles. This ridge must have formed an offshore bar or shoal when the waters stood at its hight over the Cham-

PART OF THE PLATTSBURG QUADRANGLE



SHORE LINES AT PORT KENT.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 Miles

Contour interval 20 feet.

Datum is mean sea level.

Beaches and wave cut lines

Cliff in till with base at upper marine limit

Fossil marine shells

plain valley. I have taken the level from the local contour of the Willsboro quadrangle.

Shore lines and deltas about Port Kent. By reference to the topographic map, plate 21, giving a part of the Plattsburg quadrangle, it will be seen that shore lines and deltas are to be found from Port Kent back to Keeseville on the Ausable river.

Trembleau mountain on the south is thinly covered with drift particularly on the lakeward slope from 500 feet downward. Much of the steeper slope immediately west of Trembleau point has been stripped of drift by wave action. Heavy till deposits farther inland occasion the northern slope in the form of the broad spur extending from the 600 foot contour line down to the 400 foot line. Till again appears near the lake shore in Port Kent village; though on top of the hill on the border of the streets as laid out on the map a well was sunk some 12 feet in coarse waterworn materials containing cobblestones up to 10 inches in diameter, probably waveworn materials.

Shore lines begin to appear first, as one descends Trembleau mountain, at about 590 feet. The deposits of this stage suggest the presence of ice, either floating or pan ice, by reason of the angular blocks in the rude but essentially horizontal, often spitted, beachlike deposits which can be traced where shown by the line on the map. Definite wave-heaped beach ridges appear a few feet lower at probably 580 to 585 feet in the elliptic hill crest shown on the map. The stones are subrounded in this deposit inclosing a shallow saucer-shaped depression in the center—the old lagoon of this offshore wave-heaped shoal. From this level traces of wave marks in parallel roads or occasional lines of waterworn pebbles (as along the road from Port Kent to the lowest notch in the crest of the mountain) appear down to at least the levels of the two churches in Port Kent.

Near the old tollgate site, 1½ miles west of Port Kent, the spur of till before mentioned is cut back in the form of a good sea cliff having a length of about ½ mile. The base of this cliff is at about 340 feet and is confronted by one of the delta levels of the Ausable. It would appear that the heaviest and longest wave action took place locally at this level. That the escarpment in the till is due to wave cutting rather than to stream cutting during the

retreat of the ice sheet is shown by the fact that the surface of the till spur above this level is deeply cut by what I take to be marks of wave action. Well rounded gravel is encountered at approximately this same level farther east on the northern face of Trembleau mountain, indicating efficient wave action there sufficient to pocket the material between ledges.

There is a noticeable grouping of shore lines in Port Kent between 200 and 260 feet; back of Port Kent about 350 feet; a rather persistent shore line at or just below 500 feet and in favored situations from 500 up to 585 feet. The most marked wave action in this range is at 350, 500, and from 585 to 590, because these last are the highest seen. A search above the 600 foot line over the top of Trembleau mountain failed to show higher signs of wave action.

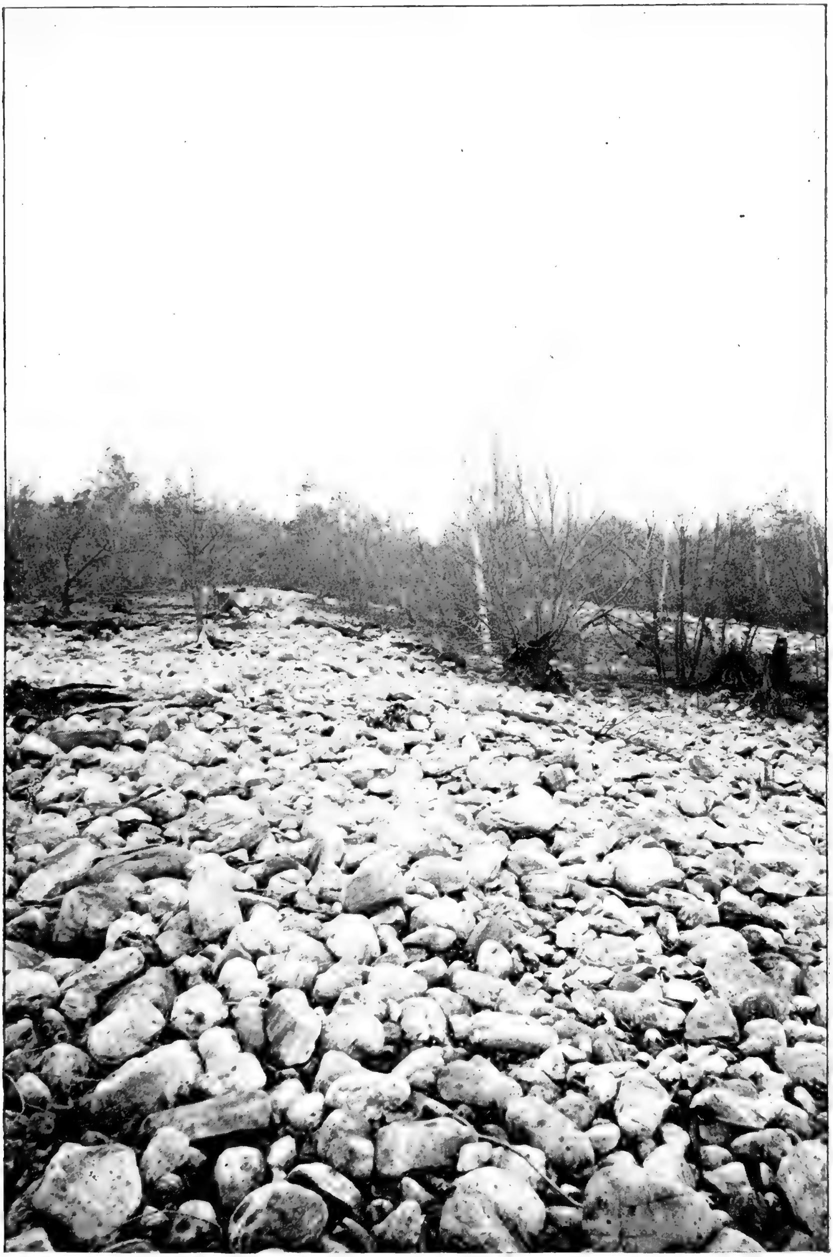
A 500 foot delta plain is extensively developed about Keeseville, both east and west, and to the south as well. About 1 mile northeast of Keeseville, a hillock rises up on the sloping surface of the delta plain with what appears to be a circular shore line as shown on the map. The strength of the delta building and that of the shore line at the 500 foot line are rather marked.

The next marked delta stage in descending order coincides with the base of the cliff above described at about 340 feet. A fragment of delta terrace lying between Wickham marsh and the Ausable, having a surface at about 250 feet elevation, accords with the wave lines in Port Kent village.

As noted on the diagram, plate 28, these shore lines and deltas appear to be correlated with a tilted series of strong and weak lines of wave action and deltas traceable southward from the international boundary. It is probable, as I have attempted to show in chapter 10, that the upper marine limit at Port Kent is found at about 340 feet. Delta building at this stage would have covered the Ausable chasm; hence, it follows that the chasm must have been cut since the land began to rise from the marine limit.

Fossil marine shells have long been found in the sands of the delta south of Port Kent station. An account of these shells will be found on page 212.

Plate 22



View looking north along the eastern slope of Cobblestone hill, just below the crest

Shore lines at Harkness. At Harkness on the hill east of the railroad station there is a beach ridge at about 500 feet (aneroid). This hill has a northeast exposure. A small stream entering the valley just east of the station has a sand delta at 510 feet. Above this delta on the hillside there is a faint shore line at 550 feet. Going up a gully excavated in gravel and sand and coarse cobbly drift, one comes to the top of an earlier deposit of the stream at about 650 feet. Above this level to 675 feet is a till ridge with kamelike contours.

Below Harkness on the east of the railroad and at the foot of Hallock hill a sandy ridge extends for 2 or 3 miles at about 380 feet elevation. The materials appear to have been wind blown.

Deltas of the Saranac. There is a heavy development of deltas along the course of the Saranac river specially between Plattsburg and Cadyville. Unfortunately this district immediately west of Plattsburg has not yet been mapped topographically.

There is a high level glacial delta just east of and below Cadyville station (732 feet) with associated kames indicating deposition in the presence of ice. Baldwin gives the elevation as 729 feet. This corresponds with a series of sand plains in the valleys west of Lake Champlain if we admit a tilting essentially parallel with that of the upper marine limit. This tilted level correlates with the bare rock spillway southwest of Schuylerville from near Quaker Springs toward the battlefield of Saratoga. The waters in these northern side valleys must have flowed along the ice margin with slight fall toward the south where a lake appears to have existed at least over the Fort Edward district.

Below this high level delta about 40 feet is another level as yet not well understood. At about 650 feet there is a large sand delta which appears to be correlated with the tilted water plane contemporaneous with the Coveville stage of the glacial lake which covered this district.

Again at Morrisonville station (449 feet) there is a broad plain at about 450 feet above the sea which appears to be correlated with the uppermost of a crowded series of beaches which extend up to 540 feet at the international boundary and decline southward. It was probable that at this time the waters did not discharge southward through even the lowest of the channels near Fort Edward

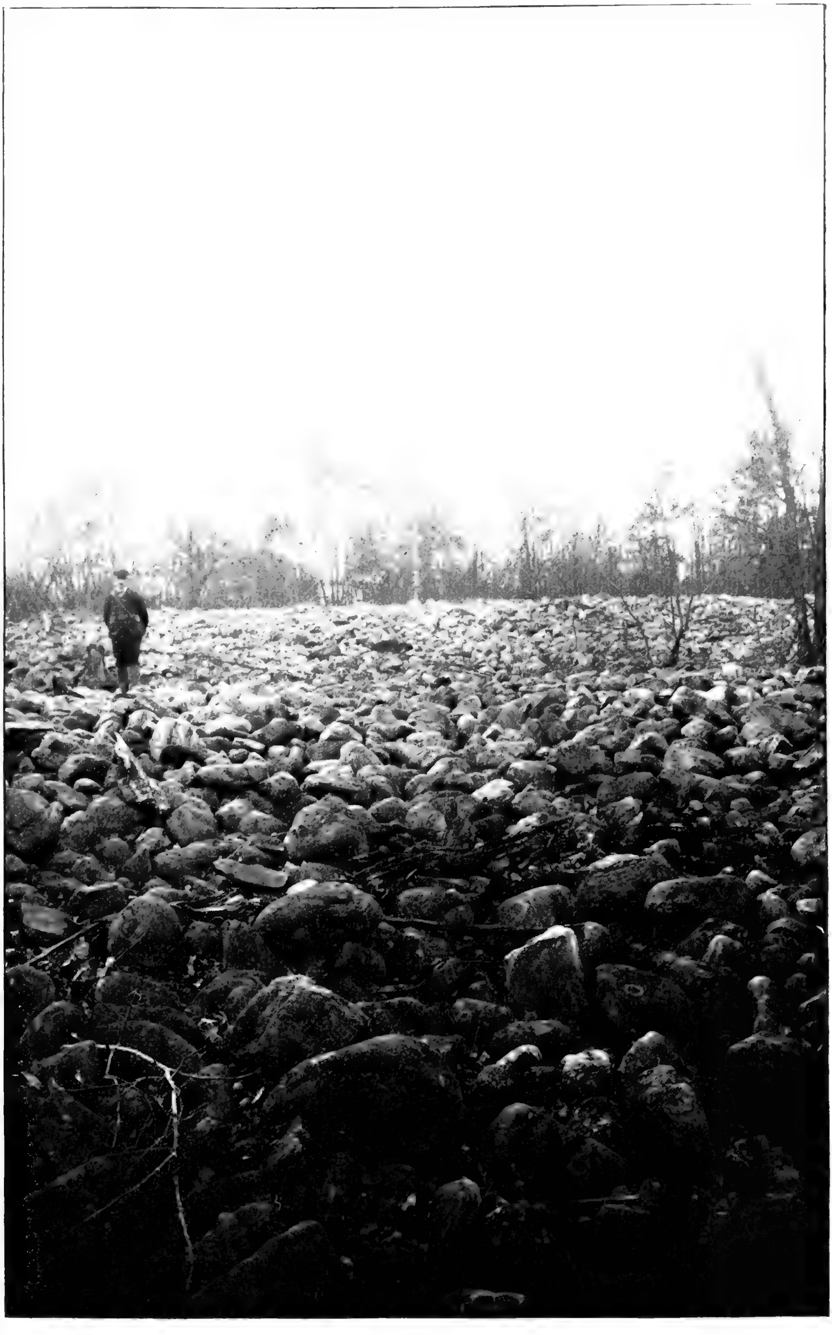
but if they were not at the sea level of the time, formed a stage of the glacial lake in which a discharge was found past the northern border of the Green mountains into the lower St Lawrence valley past the edge of the ice sheet. This is a point however which is still under investigation.

In the lower margin of this delta at Freydensburg's mills at an elevation of 340 feet marine shells have been found. There are slight topographic evidences that this portion of the deposit is separated constructionally from the broad plain at Morrisonville. Certainly this part of the deposit was made in the sea. The calculated hight of the upper marine limit at this locality is 375 feet.

Shore lines of the Mooers quadrangle. The shore lines and deltas of this area are more fully described in the special report on that atlas sheet.

Beginning on the south near West Beekmantown, there are faint traces of wave action up to nearly 640 feet. Occasionally stronger traces with definite beach ridges are found at higher elevations northward till Cobblestone hill, northwest of West Chazy [*see* pl.22] is reached when remarkably strong wave action is found as high as 675 feet [*see* station 50, pl.28]. Thence northward beach ridges occur along the northern and eastern margin of the Altona flat rock district at a slightly increasing elevation toward the north. There is a delta at Altona [*see* station 51, pl.28] with what appears to be an ice-free margin at 640 feet, and the remnants of another on the north branch of the Big Chazy river at an elevation of at least 660 feet [*see* station 52, pl.28]. North of Deer pond there are faint shore traces at about 705 feet. At Cannon Corners on either side of the English river there are hook-like bars curving into the valley mouth between 700 and 720 feet in elevation. Somewhat south of these and on the extreme western border of the area what appear to be wave-heaped materials occur as high as 750 feet. In the extreme northwestern corner of the quadrangle at the head of Kellas brook in the region known as Armstrong's Bush there is a cobblestone ridge with a recurved hook at its southern end at an elevation of 720 feet [*see* station 53, pl.28]. A short distance west of this last example at the corner of the road leading to Covey Hill postoffice and beyond the limits of

Plate 23



The crest of Cobblestone hill, showing strong wave action on boulders and large cobbles. Looking west. Elevation about 650 feet

SCHEME OF TERRACES IN DELTA OF THE HOOSIC.

the map [pl.29] there is a similar cobblestone ridge at about 800 feet elevation (aneroid). Over all the northern half of the quadrangle these isolated deposits are separated by an interval of about 100 feet from the next high mark of wave action, beginning the record along the international boundary at about 620 feet. In the southeastern half of the sheet, wave-made traces are visible from the top of Cobblestone hill down to the low ground on the east of the area.

Beginning on the international boundary in the region of Armstrong's Bush, wave-heaped materials begin to appear at about 540 feet in a closely crowded series of ridges of angular shingle extending down to about 360 feet. Southward the upper limit of this group falls off in elevation and in the vicinity of Wood Falls on the Big Chazy the highest clear beach is found at 500 feet. In the southern part of the sheet this lower series is not distinguishable from the upper series in any manner which I have been able personally to devise.

The accompanying map [pl.29], shows the location and extent of the more distinct traces of these and other beaches.

Shore lines about Covey hill, Canada. Reference has already been made to the occurrence of a well defined beach taken by Mr Gilbert to be the upper marine limit on the north side of Covey hill at an elevation of 450 feet [*see* p.162]. On plate 25, I have attempted to delineate the position of this beach for a portion of its extent. It is a very strongly developed beach for this district with well worn pebbles on its seaward face. Below it occur others toward Ste Antoine and Vicars. Accepting the terraces which come above this beach as made by waters escaping along the ice front, this 450 foot beach is the highest one found to extend from the beaches of the Champlain valley around the northern face of Covey hill. Its westward extension is known at a number of points near Sun, East Constable, Potsdam and places still farther westward. But in the district southwest of Malone the ground becomes so much broken up in the form of short hills that tracing it is difficult without a good topographic map as a guide to localities in which wave action should be looked for.

The vicinity of Covey hill is of critical interest in the solution of the problems relating to all the shore lines of the Champlain

and upper St Lawrence valleys. Any refinement or revision of the problems with which this report mainly deals should be begun at Covey hill. The absence of definite shore lines on the smooth till slope of the northern face of this eminence from 570 feet to the top is in striking contrast with the wave-ribbed slopes of the Champlain valley on the south at an equal elevation. Except for one or two faint traces of parallel roads and a small delta on the north slope at an elevation not far from 800 feet the till slope of the upper half of the hill is practically as left by the ice sheet. The failure of beaches and cliffs due to the work of waves in this upper zone just where waves would be most effective had an open body of water been present to transmit the undulations of its surface against this impressionable glacial coating is one of the most conclusive arguments for the theory of glacial barriers. I have already described the corroborative evidence as to the upper limit of standing water in glacial lakes found in the abandoned spillway and waterfall of the Gulf.

Plate 25

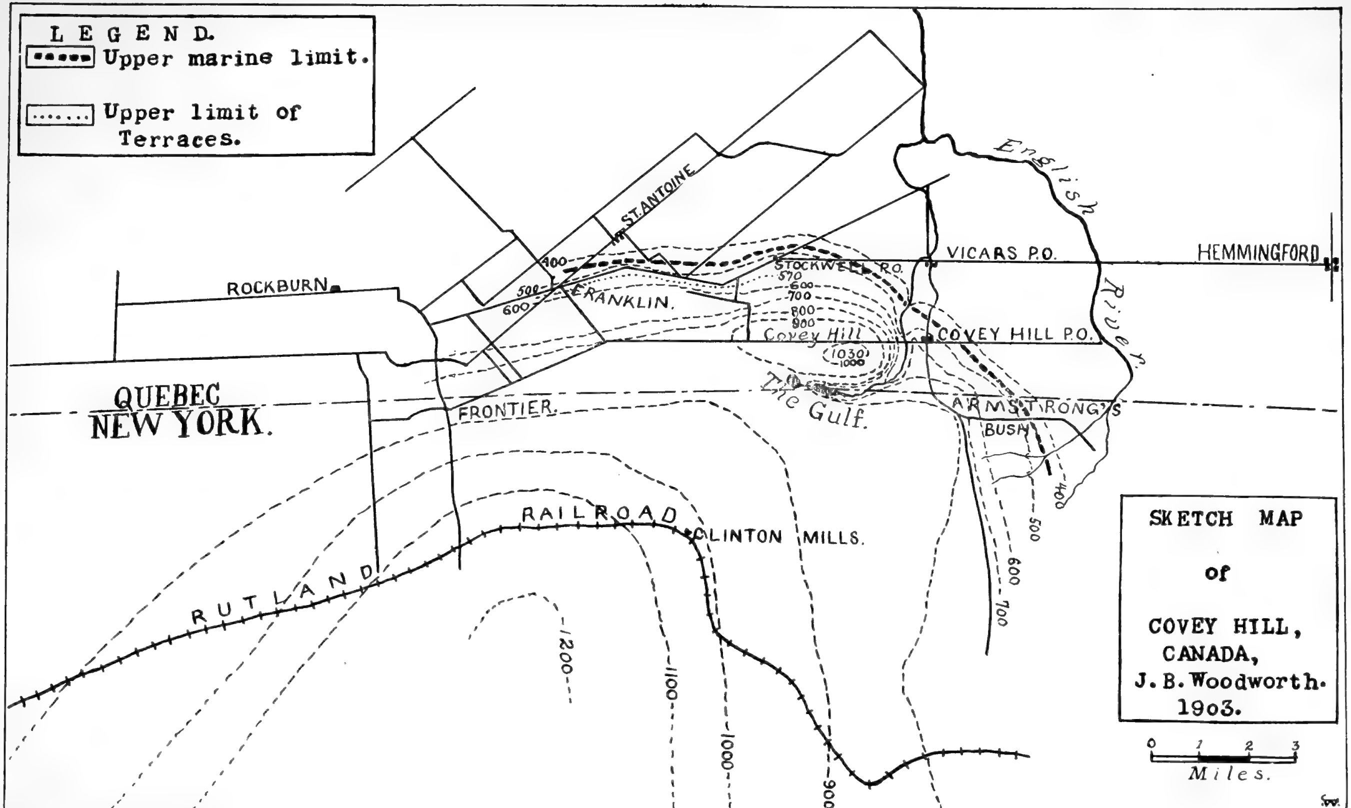

LEGEND.
Upper marine limit.
Upper limit of Terraces.
ROCKBURN
ST. ANTOINE
FRANKLIN.
STOCKWELL P.O.
VICARS P.O.
COVEY HILL P.O.
HEMMINGFORD
English River.
Covey Hill
(1030)
The Gulf.
ARMSTRONG'S BUSH
QUEBEC
NEW YORK.
FRONTIER.
RUTLAND RAILROAD
CLINTON MILLS.
400
500
570
600
700
800
900
1000
1100
1200
SKETCH MAP of COVEY HILL, CANADA, J. B. Woodworth. 1903.
0 1 2 3
Miles.

Plate 26

Upper part of the old cliff south of Sciota shown in plate 13

Chapter 8

LARGER GLACIAL LAKES OF THE CHAMPLAIN AND HUDSON VALLEYS

LAKE ALBANY

The preceding descriptions of the successive stages of frontal and marginal deposits of the shrinking ice sheet and the attendant evidences of local water bodies within the Hudson valley make it evident that as the ice front retreated from the terminal moraine, bodies of water stood at the ice front increasing in length northward as the ice withdrew in that direction. Doubtless at many of these stages the water in front of the ice might justifiably be denominated a lake regardless of the relation to sea level. If the land were at the same level as now the outpour of fresh water would have excluded the salt and made the conditions those of an estuary or lake; with the land 100 feet lower so as to bring the deltas and terraces at Peekskill south of the Highlands at sea level the same conditions would have held; if for any geographic reason the entire southern Hudson valley were above sea level at that time lacustrine rather than estuarine conditions would have prevailed. These considerations hold good also for the conditions in front of the retreating ice sheet as far north as the vicinity of Poughkeepsie at least. But north of Staatsburg and thence northward throughout the Hudson valley there is a record of continuous lacustrine conditions for a time marked by beds of clay and marginal deltas which indicate typical lacustrine conditions in the total absence of marine fossils from the beds deposited at this time. To this body of water whose clays were early designated the "Albany clays" by Ebenezer Emmons, no name is so appropriate as Lake Albany.

E. Emmons[1] wrote "the Albany clay, or as it is in other places called Post-tertiary clay," in 1843, long antedating the name Albany as used in the geology of Texas.[2] He regarded the clays

[1] Natural History of New York, division 5, Agriculture. 1846. 1:260.
[2] U. S. Geol. Sur. Bul. 191, p.42.

and the sands which overlie it as one formation. According to him the chemical composition of the clays is as follows:

Water of absorption	4.25
Organic matter	1.17
Sulfate of lime	1
Silicates	69.02
Peroxid of iron and alumina	17.24
Potash	.14
Carbonate of lime	4
Magnesia	3
	99.82

A trace of chlorid of sodium exists. No exact statement of the source of chlorid of sodium in this clay can be given. If it were marine it would be expected that considerable traces of common salt and other sea salts would be found. The trace of chlorid of sodium noted by Emmons has no bearing on the marine origin of the clays since such traces are found in the surface waters even of the Berkshire hills.[1]

Mr Asa Fitch M. D.[2] employed the term "Albany clay formation" in 1849. He stated: "As neither its geological age or name is well settled, I prefer designating it the Albany clay."

Mr Fitch[3] noted the essential continuity of the clays from the Hudson valley to Whitehall and thence into the Lake Champlain valley. In most of Washington county the clay rests directly on the Hudson river slate, though extensive beds of gravel locally intervene. East of Comstock's landing the clay is stated to be 20 or more feet thick. In a railroad cut across the river from Fort Edward, Mr Fitch noted sand layers alternating with clay with local unconformity between these beds and an overlying sand deposit containing boulders of the underlying clay beds.

Lake Albany doubtless began on the south in the waters standing in front of the retreating ice sheet prior to the opening of

[1] *See* Mass. State Bd of Health, 23d Rep't, with map. Boston 1892.

[2] Historical, Topographical and Agricultural Survey of the County of Washington. N. Y. State Agric. Soc. Trans. 1849. 1850. 9:872.

[3] *l. c.* p.873-75.

the Mohawk outlet of the great glacial lakes on the west. As soon as the ice retreated in the valley to a position north of Albany and the drainage of Lake Iroquois came into the Hudson valley Lake Albany properly came into existence.

The clays, and the deltas marginal to them, extend north of Albany certainly as far as the Moses kill. At this place the Hudson gorge proper widens out and the Albany clays which mantle the rock terrace marginal to the gorge are separable from the clays of the low grounds northward by reason of the partly ice-swept character of the surface apparently indicating that the northern limit of the lake was at one time formed by an ice margin over the Fort Edward district. That Lake Albany with the melting out of the ice from the Champlain valley became confluent with the glacial lake stages of that district is borne out by the extension of clays from one region to the other and by the extension of the water levels of the Lake Champlain area into the upper Hudson valley through the Wood creek pass.

The shore line of Lake Albany is most clearly shown by the altitude of the deltas of the larger streams which emptied into it. These include the old delta of the Mohawk, that of the Hoosic and the Batten kill and numerous smaller deposits southward in the Hudson valley. I would refer to Lake Albany only those deltas which appear to have been built in open water between the Batten kill and the vicinity of Rhinebeck. South of the last named point the deltalike deposits adjoining the Hudson gorge appear to have been built in front of the retreating ice sheet, and I am led to think that the surface of these proglacial deposits was mainly if not altogether above the level of Lake Albany at the time of its maximum development, the waters escaping from the flooded middle Hudson valley through the old gorge on the south as waters now escape but perhaps at a still greater depth owing to a higher stand of the land on the south.

It will be observed that the deltas on the eastern side of the Hudson valley from the Batten kill northward to the Poultney fail to coincide with any one plane. In a report of progress on the field work for 1900 I interpreted the falling off in altitude of the deltas successively northward from that of the Batten kill when compared with the highest shore lines about

Ticonderoga as due to a warping of the crust in the postglacial changes of level.[1] A more complete study of all the phenomena involving a correlation of the spillways about Schuylerville with delta and shore lines far to the north makes it more reasonable to suppose that these lower deltas on the north of Schuylerville were deposited in succession in the falling water levels of a glacial lake with varying but successively lower outlets lying between the site of Fort Edward and Stillwater. In this view these lower deltas were not made in the waters of Lake Albany. If Lake Albany extended northward over the Fort Edward district and connected through the passes of the mountains with the Champlain valley, its deltas should be found successively higher on the north somewhere near the altitude of the line of comparison on plate 28. Thus on the Fort Ann quadrangle the valley train of gravel and sand in the Mettawee valley above Raceville and about Middle Granville lying above the 400 foot contour line if not deposited at the Lake Albany level was at least laid down in these side valleys in probable contemporaneity with the later northern phase of this lake. There is a corresponding terrace on the western side of the Hudson valley at the base of Palmertown mountain, evidently an old delta of the Hudson but probably made in the presence of ice remnants in the valley though positive proof of this is now wanting.

Of shore lines, between the deltas there is no distinct sign of wave action though along the eastern side of the valley a few feet above the upper limit of the main body of the clays there is a zone of smoothened and straightened contouring of the ground, above which unmodified drift surfaces present a noticeable contrast. This kind of evidence is most marked from the Moordener kill northward past Troy to the Batten kill, a line which coincides very closely with the inner and upper margin of the old rock bench of the Hudson valley floor.

Correlation of Lake Albany with the western great glacial lakes. Lake Albany received on the north in the portion of its extent lying within the upper Hudson valley several large streams, the Moordener kill, Hoosic river and the Batten kill, coming from the east; on the west, the Adirondack–Hudson for a time at least, and more than all the drainage of the Mohawk valley.

[1] N. Y. State Mus. An. Rep't. 1901. p.r13.

The large delta of the Mohawk extending from Schenectady toward Albany is a witness of the fine sands and clays which poured into Lake Albany from the west, in which direction lay the great glacial lakes whose development coincided with the retreat of the ice front across the Mohawk valley. The stage of the great glacial lakes with which the delta appears to be equivalent is that of Lake Iroquois with its outlet at Rome and thence draining into the Hudson valley.

Conditions under which the Albany clays were deposited. The conditions under which gravel and sand are deposited both above and below the level of standing water are much better understood than is the case with the sedimentation of clays, particularly those deposits with which we are here concerned, the rock-flours of glaciated districts. At the present time, there is an abundant literature concerning the clays of existing and vanished glaciers, in which, however, there is scant discussion concerning the factors which control the deposition of clays.

There is a variation in the delivery of clay from a glacier dependent on diurnal and seasonal changes of temperature in the atmosphere, subject to modification by the passage over the glacier of those whirls of the atmosphere known as cyclonic movements or storms with their accompanying precipitation in the form of rain or snow.

Diurnal changes of temperature and their effect on glacial clays. With each rotation of the earth on its axis in middle latitudes, a glacier is alternately exposed to the sun's heat and shielded from this cause of melting. During the day, the effect of insolation is to swell the glacial drainage with water carrying detritus set free by the melting of the ice. Other things being equal a larger quantity of clay will be carried out of a glacier at day than at night when the streams are checked. The greater volume and velocity of the streams discharging directly from a glacier into a water basin during the day will tend to carry the suspended clay particles farther out and allow of their wider distribution by stream-made currents than at night when not only is there less clay delivered but the transporting agencies are less effective. But the clay deposited under these day conditions will contain more coarse mineral particles than the night clays when only the finest rock-flour escapes to the area of clay deposition. There

may thus arise a banding of the clay deposits, in which coarser, thick rock-flour layers near the ice margin represent day additions and thinner, finer, more unctuous clays represent night deposits.

The control thus exerted will be confused or lost where the waters discharging from different ice fronts reach the area of clay deposition through a common distributer after journeys a half day's stream travel in difference of length. In this case, the day discharge of one stream may deposit at the same time as the night discharge from another stream. A similar disturbance or nullification of the differences of day and night discharge must take place in the Rhone valley where tributary glacial streams at varying distances from Lake Geneva have their clay load delivered to the lake several days after the start of the journey. Where the clay load of day discharge from one glacier near the head of the Rhone passes a tributary fed by a glacier lower down the valley at night, the day load of one becomes mingled with the night load of the other; and thus the difference between day and night conditions in glaciers which do not discharge immediately into clay-depositing areas will not have their diurnal changes recorded in the clay areas to which they contribute. As regional glaciers draw their frontal discharge of water from longer distances than valley glaciers such as those in the Alps, it is probable that there will be less difference between day and night discharge at the front in the former than in the latter, for the reason that some of the day water of the inland ice may reach the front only after half a day's journey, thus tending to equalize the outflow. For all these reasons, it is probable that except in the case of the discharge of a single glacial stream into a limited area of clay deposition, diurnal changes of temperature will exert little control over those variations in clay laminae which are characteristic of glacial rock-flours.

Annual change of temperature and its effect on glacial clays. Summer is the time of glacier melting, winter the time of arrest of melting if not of actual freezing of glacial waters. The summer discharge of glaciers is prevalently pebbly and sandy; the winter discharge is prevalently clayey, for the streams may not then be vigorous enough to carry sand and pebbles out to the

depositing grounds. Emerson[1] has invoked this seasonal change to account for the alternate lamination of bands of fat and lean clay in the Connecticut valley, making each layer of lean clay correspond to a summer, and each layer of fat clay to a winter.

It is difficult to see how either this or the preceding variation in clay discharge will account for the essentially even deposition of alternately coarse and fine layers of clay and particularly alternations of layers of clay with layers of fine sand over a large area of deposition far from the mouth of the discharging streams, for the fine sand would go to the bottom within a short distance of the edge of the water basin where the streams entered.

Astronomical changes. Gilbert, noting the remarkable rhythmic succession in the alternation of clays and sands in certain sediments of the West compared the phenomenon with the supposed effect of periods of minimum and maximum variations in the ellipticity of the earth's orbit, the geologic effects of which were first pointed out by Sir John Herschel. But as the period of such maxima and minima in the theory proposed by Croll correspond to entire periods of glaciation and deglaciation, it is not to be supposed that the glacial clays of a single episode of deposition manifest any control exerted by these changes and we may therefore dismiss the view as having no bearing on this group of clays.

Prodelta clays. There are several other conditions controlling or interfering with the deposition of clays, particularly in bodies of water lying within or adjacent to a retreating ice sheet. One of these conditions is inherent in the method of delta construction by which a stream swings from side to side of its delta.

For illustration the simplest case will be taken, that of a glacier discharging its drainage by a single stream into the head of a bay or lake on the border of which it has already built a delta across whose surface the stream swings in the process of discharging its load of gravel, sand and clay.

While the stream is aggrading its delta, it swings from side to side through the arc whose trace is the free margin or shore line of the deposit and whose center is the mouth of the glacial stream. Take the stream at a moment when it lies at one side (say the left) of its delta contiguous to the ice front. Its burden

[1]Emerson, B. K. Geology of Old Hampshire County, Mass. U. S. Geol. Sur. Monogr. 29. 1898. p.706–7.

of gravel and coarse sand enters into the construction of the delta proper. Over the bottom of the lake or bay the clays carried out in suspension are constantly coming to rest at distances from the delta margin determined by the presence and velocity of the currents and the time taken for the particles to fall through the water. For some distance over the bottom in the path of the stream-made current, the finer particles of sand which have not at once been drawn by gravity down on the delta talus will come to rest, forming a deposit of very fine sand extending outward from that part of the base of the delta. Around the remaining portion of the area confronting the delta base, clays will deposit as elsewhere over the floor of the water body. In the course of

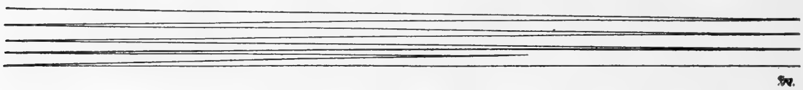


Fig. 22 Cross-section of interstratified clay and sand on lake or bay bottom in advance of a delta

a few days or weeks or months, dependent on velocity, load, and the area of its delta fan, the stream will have moved laterally across its delta to the opposite side. The fine sands will now have been deposited over the entire area in front of the delta base while clays will have been deposited on that side where sand was previously going down. Still later, the stream will have swung back to the left of the delta and sands will be depositing along that portion of the basin floor, while clays are deposited over all the area on the right. The stream thus swings to the left and right of its delta, strewing fine sand over the bottom in advance of the delta. These changes will continue so long as the stream is building up its delta and the water body is unfilled with sediment. There will thus be built up on the floor of the basin an alternation of layers of clay and fine sand, whose stratification seen in a cross-section drawn transverse to the axis of the delta will be that shown in figure 22, in which the black line represents the sand layers, the white banding, the clays.

Where the stream halts, the sand layer will be thicker than where the stream has moved steadily along in its lateral motion. At the extreme right and left, where the stream has halted and turned back on its course, the sand bands should be thicker than in the middle of its shifts.

Sand partings will ordinarily be thinner than the clay partings for the reason that the fine sand is depositing over the basin only beneath the laterally shifting, stream-made current, while clays are making everywhere else in the longer time during which the stream fails to cover the much larger segment of the arc traversed by its swings. The thickness of clay layers and sand layers will be greater the slower the rate of lateral swinging of the stream; the sand layers will thicken toward the delta, the clay layers will thicken away from it; and at a distance beyond which the fine sand is carried in suspension, the deposit of clay will be from this cause alone continuous. The rate of lateral shifting will increase directly as the load carried by the stream since the excess of detritus left on the delta plain over that carried to its edge fills up the bed and causes the current to slide off on to the part not so much built up or to give off distributaries which will naturally start out from the side toward which the stream is shifting. Thus increase in load and marginal discharge will not give rise to a proportionate increase in thickness of the prodelta sand layers for the reason that the stream will not deposit sand for so long a time over a given space, because its cycles of swinging will be more rapid.

Delta streams tend to break up into minor streams or an interlacing of streams, so that there will frequently be many lines of prodelta sand deposition, introducing minor bands of sand and clay. The breaking out and shutting off of a distributary which ends independently on the delta edge will give rise to lenticular partings of sand over the prodelta floor.

The above statement is somewhat ideal, but the prodelta clays of the small esker fan at Drownville R. I. appear to the writer to illustrate the theory here presented. It is doubtful if the regular banding of larger bodies of clay miles beyond a delta margin with an even lamination of sandy partings can be so explained. The criterion of the applicability of the explanation to any given area will be found in the thickening of the sand partings in the direction of the delta and their passage into the segment of the "foreset" beds of the delta with which they are contemporaneous along any given portion of the delta front. Observation and experiment are required to determine the distance over which fine sands may be carried in suspension in fresh, salt and brackish water.

Another source of the variations in clay texture and a cause of sandy partings lies in the fine sand and dust blown out over bodies of water by the winds. Such subaqueous deposits it is believed are more widespread than has generally been supposed. The agency of the winds is readily recognized when the product transported is volcanic ash, but in the case of ordinary sands and rock dust it is less easy to determine the wind-borne origin of the material when laid down under water.[1]

The abundant evidence of the deflation of the sandy and gravelly plains left bare by the retreat of the ice in the eastern United States and the extent to which such sands are now being blown away from one tract and accumulated on another makes it highly probable that eolian deposits would be made in bodies of water and particularly in this latitude in the warm months of the year for during the winter snow and ice protect the sand from wind action. These sands in New England usually blow during the times of dry westerly winds, for the reason that easterly moist winds by the films of hygroscopic water which they permit to collect about the dust particles cause them to adhere and resist the action of the wind. These alternations of moist and dry conditions, of easterly and westerly winds, occur at the present time with singularly frequency owing to the movements of cyclones across the eastern United States. As noted by Clayton, rainy days with easterly winds recur about once a week and so do the following westerlies. Applying this possible cause of the interlamination of fine sandy layers with the glacial clays as they occur in the Upper Hudson valley, the clay layers would correspond to times of wet conditions when discharge from the ice would be most active; and the films of sand would correspond to longer or shorter episodes of strong westerly winds according to the thickness of the bands. In this view, the summer time of marked development of the interlamination should be distinguishable from the winter time of almost continuous clay deposi-

[1] For instances of wind-borne dust and fine sand showered down over water bodies, *see* Verbeck, Chevalier. Krakatoa and the appended charts; Reclus, E. New Physical Geography, vol. 2, The Ocean. N. Y. 1886. p.198–200; Darwin, Charles. Naturalist's Voyage Around the World. N. Y. 1887. p.5; Marsh, G. P. The Earth as Modified by Human Action. N. Y. 1874. p.545–608; Bather, F. A. Wind-worn Pebbles in the British Islands. Geol. Ass'n Proc. June, 1900. 16:396–420, with bibliography; Meunier, S. La géologie expérimentale. Paris. 1899. ch. 6. p.208–16.

tion uninterrupted by dust and sand falls not only because of the anchoring of the sands by ice over the dry land but also by reason of the ice covering of the lakes or estuaries in which the clays were deposited.

In this view, the sand partings of clays in this region should be thickest on the western side of the clay area and should wedge out to thin layers on the east, due allowance being made for the drifting, by currents, of the dust which falls into the water.

The interpolation of sand partings by recurrent wind action in something like cycles of one week agrees more closely with the probable rate of deposition of the observed strata than the supposition that the alternations depend on seasonal or diurnal changes; and instead of allowing 5000 years for the deposition of the clays in the Connecticut valley, for instance not more than one 50th part of that time would probably suffice under the conditions of excessive discharge of rock-flour from the neighboring melting ice sheet.

The sandy partings in clay often simulate the loess in character and it is in them also that the equivalents of the "loess pupchen" or "clay dogs" are frequently found. There is good evidence that many areas of loess are of eolian origin; but the sandy partings in subaqueous clay areas differ from loess in that the sand has come to rest beneath a water body rather than on an open air surface.

Succession of glacial clays. It has already been pointed out in the chapter on the effects of retreating glaciers how deposits on the same stratigraphic plane may be of different ages or stages of glacial retreat. Each proglacial delta has its supplement in clays extending from beneath it over the low ground in front of it. Thus the fact that in the lower Hudson valley we find clays underlying gravels and sands does not show that there was first a time of clay deposition followed by one of coarser deposits unless it can also be shown that the gravels and sands were simultaneously deposited by normal streams. The ice contacts in that region point clearly to a succession from north to south as the ice front receded.

Exceptional reasons for predominance of clay deposits in the glacial series of the Hudson valley. The dominance of clays in the Hudson valley from the Highlands to the mountains which

shut the lowland off on the north about the margin of the Fort Edward plain is in great part dependent on the preglacial history of the district. Throughout this area the graptolitic rocks forming the argillaceous facies of the Lower Siluric known as the Hudson river group and comprising the Lorraine and other bodies of fossiliferous shale form the walls and floor of the Hudson river valley and its gorge. All of the glacial erosion on this terrane could not but produce clay at every step in the trituration of the material. The shales even where more or less mountain built and cleaved give way in small bits rather than those large fragments which the ice sheet was enabled to drag out from jointed sections of the harder rocks in the districts on the east and west. To this original clay of the valley there was added the rock-flour brought in from the higher grounds of the valley sides whenever and wherever the drainage was free to concentrate in the main channel. Moreover during the draining of Lake Vermont (glacial Lake Champlain) much clay was moved southward and left in the upper Hudson valley.

Organisms of the clays in the Hudson river valley. A long and fairly diligent search has been made for fossils in the Albany clays and the earlier deposits which occur farther south in the Hudson river valley but without the finding of fossils which indicate the presence of the sea during the stages of clay deposition.

Ries has discovered the spicules of a sponge (Hyalonema) and fresh-water diatoms *Navicula gruendeleri* As., *Navicula permagna* Edw., *Melosira granulata* (Ehr.) Ralfs., *Nitzschia granulata* (Gruend). He also reports finding impressions in the blue clay at Croton Landing which the late Professor Hall regarded as worm tracks.

I have collected small sinuous trails from the clays at South Bethlehem agreeing closely with those mentioned by Emerson[1] from the clays of the Connecticut valley and referred to the larva of a dipterous insect (*Chironomos motilator*).

J. Eights in 1852 described fossil leaves from the clays near Albany. Emerson[2] mentions leaves known as *Mitchella repens*

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[1] Emerson, B. K. Geology of Old Hamden and Hampshire Counties, Mass. U. S. Geol. Sur. Monogr. 43, p.720.

[2] *l. c.* p.718.

from the Hudson river clays and refers then to *Vaccinum oxycoccus* abundant in the Connecticut clays.

Other observers have from time to time reported fragments of wood and lignite in clays in or about the river gorge but much of this material appears to be of more recent origin than the strictly glacial and Albany clays (see paper by Fitch in bibliography at end of this report).

Indian shell heaps occur along the banks of the Hudson at various places, composed largely of the shells of oysters and these have occasionally been seen in situations which led to the belief that they were in place in the sands overlying or interstratified with the clays. An examination of such a supposed case on the Croton delta showed Professor Grabau and myself that the shells were in a talus and derived from an old shell heap at the top of the bluff.

As for the remains of a reindeer found at Sing Sing (Ossining), I do not know the circumstances under which it was found; but its occurrence is consonant with the view of nonsubmergence of the lower Hudson valley.

So far as present evidence goes it appears safe to state that no strictly marine fossil has been found to be indigenous in the waters in which the clays were deposited from the mouth of the Hudson to the vicinity of Whitehall; and further that no estuarine species are known in the clays or sands. This does not mean that the clays were not deposited at sea level with a communication with salt water on the south or at the north but that they may have been laid down at or as far above sea level as their geologic environment may demand.

Landslips. The disastrous landslips characteristic of many clay areas, as for instance those of the St Lawrence valley described by the late George M. Dawson[1] and the recent catastrophe in Norway reported by Dr Hans Reusch,[2] are not likely to occur in the Hudson valley for the reason that over the great portion of the clay area these deposits lie on the dissected and glaciated rock terraces of the river. There is no great thick deposit of clay

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[1] Abstract in Am. Geol. 23, p.103.

[2] Reusch, Hans. Norges Geologiske Undersögelse, no. 32, Aarbog for 1900, Kristiania. 1901; Nogle optegnelser frè Vaerdalen, p.1–32; Jordfaldet ved Morset i Stjordalen, p.32–44; The Landslip at Morset, p.226–28. Some notes regarding Vaerdal, p.218–26.

in the Hudson valley. Still there are narrow tracts bordering the river bank as at Newburg where inconsiderable slips might cause much damage or loss of life. The confinement of the river within its rock gorge is a further protection to the masses of clay which remain on the borders of the river.

Landslips in a glaciated district particularly where clays are covered with gravels and sand or glacial till often simulate the irregular topography peculiar to undisturbed glacial deposits. Even the structure of glacial deposits may in some cases simulate broad landslip movements for the reason that under the pressure of overriding ice the subjacent loosely textured deposits have been disturbed in much the same way as in normal landslips; but the association of glacial features such as the indications of the former front of the ice sheet and the distribution of the deposits usually make it possible to discriminate landslip topography from glacial topography.

Contorted clays. Contorted clays have long attracted the attention of observers in the Hudson and Champlain valleys. Ebenezer Emmons[1] noted contortions in the clays at Albany and as early as 1846 referred the phenomenon to the sliding of upper beds over lower ones in the movement of the clay bank toward its unsupported edge. This explanation appears to be satisfactory for many cases in the clays laid down after the final disappearance of the ice sheet from the district. It finds confirmation in the numerous instances of the sliding of masses of clays or landslips which have been observed at one point or another along the banks of the Hudson.[2] The contortions can only indicate the beginning of a restrained movement of this nature. But there are other ways in which contortions may have arisen in this field, viz, through the advance of the ice sheet on the clays laid down about margins of the ice, and through the lateral flow of clays from the growth of superposed deltas of sands and gravels about the margin of the clay tracts, a cause of contortion in clays noted by Russell[3] in the dessicated Lake Lahontan of the Great Basin.

Contortion through the forward push of the ice along its margin is to be suspected in the case of the contorted clays in the basal portion of the section on Croton point; but the contortions can

[1]Emmons, E. 1847. *See* bibliography, 53.
[2]Dwight, W. B. 1886. *See* bibliography 45.
[3]Russell, I. C. Lakes of North America. Boston 1895. p.50, fig.7.

not be taken as a criterion of the presence of the glacier unless independent evidence of the presence of the ice be found and even in this case the direction of the overthrusting movement shown by the clays should agree with the axis of movement of the ice margin. As this movement in the clays would be away from the ice contact terrace it should be possible to discriminate in favorable situations contortion through gravitative sliding from contortion by ice thrust. In the Croton point case, there is evidence of the presence of the ice in the morainal revetment of the remaining portion of the old ice contact terrace on the north and the contortions have

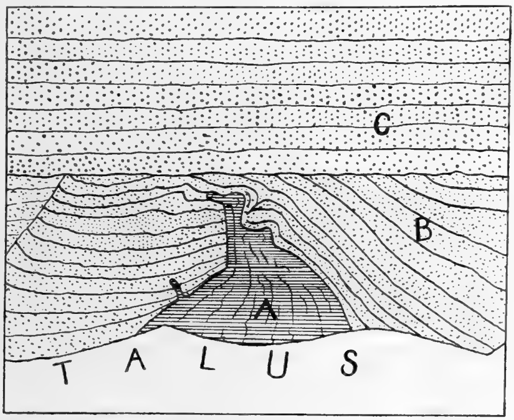


Fig. 23 Contortion and intrusion of clays in sand bank south of Port Kent railroad station, as seen July 31, 1900: A, the clay; B, the foreset sands of the delta; C, upper most undisturbed sand layers

their axial planes thrown over to the south away from the ice, hence it is possible to infer that a slight ice thrust is indicated here.

The case is described elsewhere in this report in which the ice sheet has overrun clays in the Hudson gorge between Schuylerville and Fort Edward, producing contortions of large size.

At many points where streams have constructed deltas on the margins of the clay area crumpling is to be suspected as an effect of the weight of the overlying sand and gravel. A rather marked case, probably a locality earlier observed by Ebenezer Emmons, is that of the southernmost lobe of the marine delta of the Ausable exposed in a section south of the railroad station at Port Kent on Lake Champlain. The sands which have here been deposited over the clays have resulted in the disruption of the latter in the manner of irregular dikes penetrating the overlying sands.

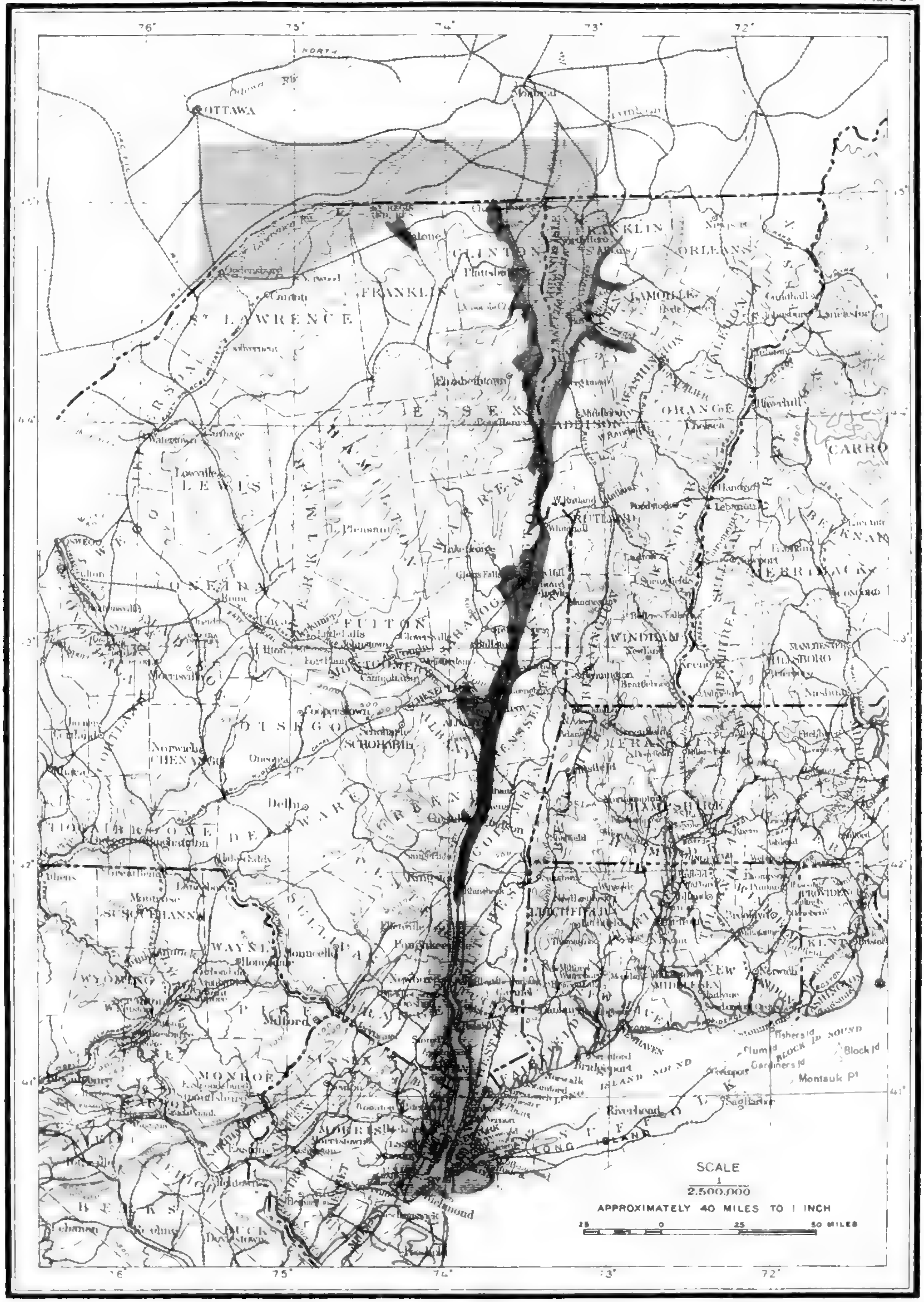
Chapter 9

LARGER GLACIAL LAKES OF THE CHAMPLAIN AND HUDSON VALLEYS (continued)

LAKE VERMONT OR GLACIAL LAKE CHAMPLAIN

From the failure of the higher shore lines of the Lake Champlain district to pass around the northern spur of the Adirondacks at Covey hill and thus westward along the northern flank of the mountains it seems as before stated necessary to postulate an ice dam across the mouth of the Champlain valley acting as a barrier to retain the waters in it up to these higher levels. The waters thus confined in the Champlain valley already recognized by Baldwin, Upham and others, have been referred to as glacial Lake Champlain. As this body of water was of far greater extent than Lake Champlain and came into existence independently of this smaller lake and moreover was separated in time from Lake Champlain by a marine episode in the valley, it seems best to employ a distinctive name. As the glacial lake covered practically much of the state of Vermont west of the Green mountains and probably penetrated through that range at its highest stages to the basins on the east of the mountains, "Lake Vermont" is used here instead of the descriptive phrase heretofore employed.

This body of water was apparently at first as noted by Upham confluent on the south with what is in this paper denominated Lake Albany. Just how far north in the Champlain valley the ice had retreated at this early stage depends on the interpretation of the higher gravel ridges and beachlike deposits in the northern half of the Champlain valley. On the extent to which the ice had retreated depends in turn the extent at any time of the lake toward the north. The outlet of these ice-dammed waters at this early stage of confluence across the present divide of the Hudson and Champlain basins is a matter which concerns the interpretation of Lake Albany on the south and is considered in that connection. Lake Vermont may be said properly to have come into existence when in consequence of a local lowering of the waters south of Fort Edward a discharge began across a barrier into the Hudson valley on the south.



Geology by J B Woodworth

CHAMPLAIN	LATE WISCONSIN	
Marine Deposits	Deposits of Lakes Albany and Vermont and deltas about Malone.	Retreatal glacial deposits of Southern Hudson Valley.

Map of Lakes Albany and Vermont, and the Champlain marine deposits

Before passing to the notice of the outlet of Lake Vermont, it is desirable to determine, if possible, from the facts in hand the nature of the change which brought about a separation of the clay-depositing waters which extended from the upper Hudson valley into that of Champlain. On plate 28 of this report, a line (A–B) is drawn on the profile for the purpose of comparing certain water levels which occur at indicated points on the sides of the Hudson and Champlain valleys. The plane in which this line lies has a tilt from north to south at the rate of about 2 feet to the mile. The line is drawn through two of the highest beaches found between Port Kent and Sawyers hill at Street Road on the New York side of Lake Champlain. It is possible that these beaches are not contemporaneous. From Street Road to New York city there are practically no kettle holes now remaining unfilled in the drift below the levels which this inclined plane traces on the sides of the valley, except it be that the large kettle holes in and about Glen lake descend below the plane, with their tops, however, well above it. The kettle holes quite uniformly fall off in level to the south in rude parallelism with this plane of comparison.

From the southern border of the Highlands of the Hudson southward the sand plains and terraces contemporaneous with the retreating ice front rise to the northward in succession in close parallelism with this plain and approximately to equivalent elevations. Throughout the middle Hudson valley there is less accord in elevation of the actual deltas and this projected plane of comparison. It has proved well nigh impossible to find any systematic relation of the various water levels which are indicated in this portion of the valley, after making due allowance for such deposits as appear from their form or structure to have been built in waters confined along the ice margin or held up on the rock terraces of the Hudson gorge by ice remaining in it. In general there is clearly indicated, however, a rise of the water levels toward the north at something like the same rate of tilting as that indicated by the line of comparison; but the upper limit of the deposits falls below that of the plane of comparison as if at this later stage of delta building along the ice border in the river either the land had risen or, if it were

already well above sea level, the outflowing stream in the gorge on the south had more deeply excavated its channel so as to permit the draining of the waters of Lake Albany and the region on the north to a lower level. A general southward tilting of the whole region would have accomplished the same result during the early lake stage.

In choosing between the above views, it has to be noted that after the barrier was instituted in the upper Hudson valley between the lake waters of the Champlain and Albany districts the water levels established in the former area according to my interpretation of them as shown in plate 28 are tilted now much more steeply than those of the Albany clay region in the middle and southern Hudson valley. On account of the apparent close approximation of the water levels in the lower and middle Hudson valley to the line of comparison above mentioned it seems probable, though not to my mind thoroughly demonstrated by the analysis I have been able to make of the mass of details presented by the district, that the land remained fairly stable during the retreat of the ice sheet from New York narrows northward, such changes of level as are indicated by the altitude of the proglacial deltas and terraces being due to fluctuations in the water levels and the excavation of the drift in the Hudson gorge during the time that Lake Iroquois discharged through the Mohawk valley into Lake Albany. The land was then relatively to its present attitude tilted down on the north so that the line of comparison in plate 28 was essentially parallel to sea level. Following this essentially stable phase an actual down tilting to the north ensued with an axis of no change of level somewhere not far north from Albany, bringing the Champlain district into parallelism with the later shore lines including the marine limit as indicated in plate 28, and producing a corresponding uplift in the lower Hudson valley. This change of itself would have produced a rise of the waters in the glacial lake on the north of Albany in an increasing ratio with the northing and an apparent lowering of the shore lines in the valley south of Albany. This probably was the time of maximum water hight over the divide south of Fort Edward. The excavation or reexcavation of the Hudson gorge in the far south, favored by the increased current

due to the influx of waters from Lake Iroquois, gradually lowered the level of the waters in the lakes on the north till Lake Albany as such was drained, leaving Lake Vermont behind barriers of at first superficial deposits in the Schuylerville district and when these had been breached by the excurrent stream it was still held in by the divide in the floor of the Wood creek channel near Fort Edward. This hypothesis which regards the whole of the eastern part of the state as moving blocklike without essential warping in the tilting appears to me to have more support than the idea of warped levels. It regards the land as tilting down on the north as the ice went off, remaining down for a time, and then beginning the reversed upward movement which probably is still in progress over the north as its opposite is taking place at the mouth of the Hudson.

Outlets of Lake Vermont. The question of the outlets of Lake Vermont, the glacial lake held in over the site of the present lake Champlain and extending southward into the Fort Edward district, to which reference has been so frequently made in these pages, has not been completely exploited as yet by field work. The principal points remaining undetermined concern the possibility of an early high level stage of overflow through the Winooski valley into the Connecticut and a leaking out of the waters along the northern end of the Green mountains past the ice sheet into the St Lawrence gulf at a late stage in the lake history just before the marine invasion. Between the very high and the very low stages of level at which these contingencies might arise in the situation of the outlet of waters over the Champlain area there are a number of data which point to the location of outlets accordant with the intermediate lake levels on the hypothesis of tilting to the south. These outlets lie between the vicinity of Fort Edward and Stillwater in the upper Hudson valley coincident with and south of the present divide between the Champlain and Hudson basins.

The outlets in this vicinity are described below under the title of the Quaker Springs, the Coveville (or Dovegat), and the Fort Edward outlets.

Quaker Springs outlet. The surface of the western terrace of the Hudson gorge in the vicinity of the battlefield of Saratoga from near Quaker Springs southward to Stillwater is partially

stripped of its coating of clay and sand indicating as pointed out in the first part of this report that a powerful stream of water coursed over this path previous to the reexcavation of the Hudson gorge. This stripped floor has an elevation of about 280 feet above the sea near Quaker Springs. The stripped character of the ground is not perhaps at first easily perceived for the reason that the Hudson river slates and shales break down into clays very readily. On many of the farms in this belt the disintegrated and partly decomposed shales are directly invaded by the plow.

When water flowed over this bench the delta of the Batten kill must have extended in something like its original contour over the gorge of the Hudson and the Coveville channel near Schuylerville. The Albany clays must also have filled the Hudson gorge on the south. The occurrence of this spillway marks a new episode in the upper Hudson valley, the draining away of Lake Albany, and the beginning of the reexcavation of the Hudson gorge so far south as that had been filled by the clays of this lake. It remains to determine if possible the condition of the geography on the north of this spillway.

It should be stated that the writer was led to consider the Quaker Springs scourway as associated with the outlets of a glacial lake on the north on observing that a plane passed through certain higher water levels in the Adirondack region [*see* the line T–U, on pl.28] came to the level of the Hudson terrace precisely where this phenomenon of stripping was most marked. There must have been for a considerable length of time a very strong discharge of water along the ice margin and the western wall of the Adirondacks southward into the Hudson valley, following the ice edge throughout this distance so far as the ice still remained in the depressions or discharging into lakes of varying level at the ice front. The line above referred to has been drawn nearly parallel with that taken to indicate the marine limit at a later time. It will be noted that the plane nearly coincides with the top of the glacial terrace at Street Road as well with the later shore line imposed on the slopes of that marginal delta. Though what I have taken to be traces of the shores of water bodies occur along this plane of tilting northward to the international boundary in the embayments of the Cham-

plain valley I have been unable to find along this plane north of the Street Road locality traces of shore lines in exposed situations where an open lake would leave traces. It seems to me therefore not demonstrable at present that the actual ice front had retreated very far north in the Champlain valley at this stage but that more likely there were glacial lakes of the Marjaelen See type though probably larger than this example occurring here and there along the ice margin at approximately the same level and draining from one to another southward.

This plane if followed northward will be found to graze the northern half of the Batten kill delta, which appears to have been built later than the southern half; it falls on a 580-foot beachlike deposit in the southern part of the Port Henry quadrangle, and on a lake (?) terrace at 600 feet at Elizabethtown on the quadrangle of that name, on the upper Bouquet river, a tributary of Lake Champlain; it touches a high terrace deposit also on the Bouquet river branch in Lewis on the Ausable Forks quadrangle 2 miles north of Towers Forge at an elevation of 620 feet. On Black brook (Ausable Forks quadrangle), there are broad stream plains between 660 and 680 feet in elevation west of Clintonville; also plains at 700 feet at Clintonville: all in this tilted plane. This plane also strikes the Saranac river at an elevation between 720 and 740 feet. Cadyville station is 732 feet; just east and slightly lower (729 feet Baldwin) is a large delta probably of this series. The plane would meet the international boundary between 820 and 840 feet. Just west of the Mooers quadrangle is a beachlike ridge indicating some kind of water action at this level, approximately that of the upper lakelet at the Gulf.

The Cadyville delta is associated with kames; the Street Road terrace was clearly built between walls of ice on one side and of rock on the other. Both deposits are below the level of the upper part of the great spillways on the Mooers quadrangle. If the land stood during these stages at anything like the attitude assumed during the ensuing marine invasion, these glacial deposits may be considered as nearly contemporaneous, thus carrying the ice down to the vicinity of Ticonderoga.

All that can be at present stated with confidence concerning Lake Vermont during the discharge at the Quakers Spring outlet is that the ice appears to have been retreating and shrinking in

the Champlain valley and that it had withdrawn as far north as Street Road but probably had not withdrawn as far north as Trembleau mountain at Port Kent.

Coveville outlet [*see* pl.11]. One of the singularities of the gorges lateral to that of the Hudson in the upper valley of the river is the arrangement of the Hoosic opposite that of Round lake, and farther north the opposition of the channel of the Batten kill to that of Fish creek the present outlet of Saratoga lake. The only feature however of these side gorges to which sufficient attention has been paid in this survey to warrant discussion is the old channel of the Hudson west of Schuylerville. Between Northumberland and Bacon Hill a trough about 1 mile wide at top and ½ mile wide over the floor overhangs the present gorge of the Hudson and extends southward to Grangerville where Fish creek valley enters it from the west. From this point the old trough extends southeastward to the west bank of the Hudson below Schuylerville, there overhanging the floor of the gorge at Coveville (the Dovegat of the Revolution), a remarkable recess in the western wall of the gorge. At Northumberland the restored contour of the floor of this old hung-up channel would make its present elevation about 220 feet above the sea; at Coveville the floor of this hanging valley is about 200 feet above tide. The cove at Coveville in its relation to this hanging valley shows clearly that a large stream at one time flowed southward over the wall of the gorge at this place into the main gorge of the Hudson river, and was arrested after a slight amount of cutting had been accomplished.

Fish creek now enters this old valley at Grangerville, flows along its eastern side for about 2 miles, turns sharply northeastward through a narrow and steep valley to the Hudson on the southern limits of old Schuylerville, falling approximately 100 feet in a distance of 2 miles.

The Hudson river must have at one time flowed through this Coveville valley at a time when the bed of the river was in this latitude approximately 100 feet higher than it now is. The 220 foot elevation of the old valley back of Northumberland coincides closely with the terrace on the east side of the river above Thompson and thence northward to the Moses kill. Furthermore the delta of the Batten kill northwest of Bald Mountain

settlement displays an eroded edge. Similar indications of the old level of the river exist on the west bank of the present gorge opposite Fort Miller. This drainage must have been active since the building of the delta of the Batten kill and before the reexcavation of the straight gorge from Fort Miller to Coveville, an inference which carries with it the corrollary that the old gorge was filled with drift at least from Coveville to somewhere near the mouth of the Moses kill. The occupation of this old side valley must have been relatively late, after the disappearance of lakes in the upper Hudson valley south of Fort Edward and likewise after the gorge below Coveville had been cleared of the sands and clays which must earlier have partly or wholly filled it.

The evidence of an old shelving water fall at Coveville shows that during the time a discharge was taking place through the outlet, the bottom of the Hudson gorge was there above sea level. What appears to be the old pool is now about 100 feet above sea level.

On the diagram, plate 28, the line C–D is introduced to show the beaches and deltas which it is believed are correlated with this outlet. It marks perhaps the most extended state of Lake Vermont exception being made of the addition which was later to come from the further retreat of the ice from the country north of Cobblestone hill near West Chazy.

Before turning to the lowest outlet, the following account of the phenomena in the lower valley of the Moses kill serves to show an intermediate stage in the excavation of the old drift filling of the Hudson gorge as well as in the outlets of the lake on the north.

Washed rocks near the mouth of the Moses kill. About a mile above the confluence of the Moses kill with the Hudson river the gorge widens out into a lower valley into which several streams come down from the terraces of the Hudson on the south and west with a backhanded drainage. The Moses kill entering this way on the east, turns sharply, once it is in this valley, to the southwest and hesitatingly enters the Hudson flowing first through a narrow vale between the main wall of the terrace and an outlying spur of rock on the floor of the valley. This spur composed of the Hudson river slates and characterized locally by a

needle slate structure, is almost completely bare of drift or clay. The entire knoll to the hight of nearly 60 feet shows signs of water action and strong scourways exist between minor knobs at its western base. The course of the current which did this work was evidently through the open valley in which Durkeetown lies and which joins the Wood creek valley near Dunham basin. The divide in this valley east of Fort Edward is about 170 feet; and the divide in the Fort Edward channel occupied by the canal is now lower having an elevation of about 150 feet. Both channels have been swept by strong currents, but as already indicated there are evidences in this field that the eroded clays in the low grounds about these channels as well as in the gorge of the Hudson are an early glacier-disturbed series.

Fort Edward outlet. The next lower stage of the glacial lake must have been determined by the hight of the divide in the bed of the Wood creek channel near Fort Edward. This broad almost level channel bears every mark of having been scoured by waters flowing through it. On the diagram, plate 28, I have correlated the deltas and beaches along the line E–F with this outlet. This was the lowest point of discharge on the south for glacial confined waters in the Champlain district. As shown later the marine limit appears to have fallen short of this col. In what manner the waters of the glacial lake fell to the level of the marine limit appears to be indicated by the crowded beaches along the international boundary where successive stages of lower and lower water levels are shown from about 540 feet downward. It is in this view almost necessary to suppose that the waters leaked out under or past the ice sheet along the northern border of Vermont. An examination of the country between Richford Vt., and Frelighsburg, Quebec, in 1904 failed to discover spillways. This is a question which has yet to be more fully investigated.

Reexcavation of the Hudson gorge. The history of the changes in the outlet of Lake Vermont in the region about Fort Edward and Schuylerville finds its parallel in the Hudson gorge farther south. Not before detailed mapping is done will it be possible to correlate all the lower terraces which record the changes which took place as the river sank toward its present bed. Some of these changes it can be shown took place very early in the southern part of the Hudson gorge and others very late in the history of

the removal of the glacial filling of the gorge. Of what appears to be an example of the first class the Moodna case is cited below. Other instances as that of the Kenwood terrace and the effects of the dissection of the delta of the Hoosic are certainly due to post-Albany changes of water level.

Terraces of the Moodna kill. The Moodna kill entering the Hudson gorge between Newburg and Cornwall [*see* pl.4] exhibits several minor terraces developed in the dissection of the heavy glacial terrace which stretches along the river bank at Cornwall. On the south side of the stream near the Hudson there is a clear record of a strong current of the Moodna depositing coarse gravel on the floor of the stream at the level of about 100 feet above the present surface of the sea. A deposit of this character so near the Hudson gorge and in soft material admitting of no fall indicates a local water level in the gorge about 100 feet higher than now. The same levels obtaining in the region about New Hamburg at the time the ice front was in that vicinity makes it very probable that this stage of terracing in the Moodna kill occurred as early as the Newburg stage and has nothing to do with the later stages of river work. There is a lower terrace in the Moodna kill at about 50 feet also well developed.

Kenwood terrace. What is here called the Kenwood terrace is a narrow somewhat shelving remnant of a terrace left by the Hudson in sinking its bed through the clays of its gorge just below Albany. On the right bank of the river from the city of Albany southward to and beyond Glenmont the edge of the Mohawk delta comes to the margin of the gorge with its summit line between 180 and 200 feet, rarely rising to 220 feet. The failure to reach the 200 foot level is noticeable where postglacial erosion has taken place. The localities in which the line rises above 200 feet are conspicuous where underlying older deposits pierce the delta clays.

From McCarty avenue to Kenwood this upper terrace is confronted by a lower one with a deeply notched frontal slope. The northernmost spur thus formed is outlined by the 140 foot contour line and two southern ones by the 120 foot line. At Kenwood, denudation has uncovered the bed rock at about this level. South of Kenwood the 120 foot bench is quite distinct, gradually falling to about 100 feet just north of Glenmont. On the south of

Glenmont the 100 foot contour line embraces the continuation of this old terrace till it blends with the flats in the vicinity of Wemple. The terrace thus marked out near the 120 foot level is probably a congeries of terraces. It is noticeable that the system falls about 40 feet in a distance of 4 miles from north to south.

Dissection of the Hoosic delta [*see* pls. 10 and 24]. The delta of the Hoosic river constructed on the borders of Lake Albany at a level now as high as 350 feet above existing sea level has been dissected by the stream in its adjustment to the local Hudson drainage base. In this dissection, the Hoosic river has meandered in a most complicated fashion in the clays and sands of the delta terrace, leaving a rather confusing tangle of terraces within the gorge. The adjoining plate 24 shows the position of the more prominent of these terraces, which are grouped on the hypothesis that the uppermost are the oldest and the lowest the most recent, that those at approximately the same level are approximately of the same age. It will be observed that the highest terrace developed at 300 feet is traceable in the middle of the gorge; that below this is a series of fragmentary terraces from 280 feet near the rock falls to 260, 240, 220, and possibly indicated by one of the 200 foot benches near or at the mouth of the gorge. This last group was probably not made at one movement of the stream but represents several ancient grades in the sinking of the stream from 300 feet to 200 feet in the soft clays and sands below the rock at the falls.

The 200 foot terrace level is widely developed in the middle and lower part of the gorge and seems to indicate waters running at about this level in the Hudson gorge for a considerable length of time. Then follows a brief stage at 150 feet; followed by well incised meanders at 120 feet, and a brief stage at 100 feet. From this 100 foot level there appears to have been a drop rather quickly accomplished to the present channel which enters the Hudson at about 80 feet above sea level.

Scant as are the evidences here adduced there are other similar facts yet to be studied in this field, pointing to the filling of the gorge of the upper Hudson with drift deposits and with the overlying Albany clays, and to their subsequent removal on the withdrawal of the waters of Lake Albany and the entrenchment of the new Hudson river in the old gorge.

Chapter 10

THE MARINE INVASION

It has long been well known that as the Wisconsin ice sheet disappeared from the margin of its gathering grounds in Ungava, the sea at once covered large tracts about the shores of Hudson Bay, throughout the St Lawrence valley, along the coast of New Brunswick, Maine and New Hampshire, and probably also a narrow strip of the coast of Massachusetts north of Boston. The main geologic problem awaiting solution in these fields is that of determining the upper marine limit. The literature of the field presents the greatest variety of opinion on this subject, the vertical and horizontal range of the marine waters being limited by each writer according to very different criteria. While the earlier writers as a rule were inclined to regard the submergence as of great depth and wide extent, recent investigators exercising a closer and more cautious discrimination between the effects of glacial waters, lake waters and those of the sea have tended to restrict the submergence to narrower limits. As will be observed I have come to an essential agreement with Baldwin[1] whose paper on the Champlain district has the merit of including a diagnosis of the marine limit on the Vermont side of the valley.

THE UPPER MARINE LIMIT

The criteria appealed to by different geologic writers in the establishment of the upper marine limit in this part of North America indicates a wide diversity of opinion as to the effects of marine action and consequently as to the extent of the postglacial submergence in this district. All are agreed that the upper limit of marine fossils is a trustworthy though probably a minimum measure of the vertical extent of the submergence. Most geologists would probably also accede to the zoologic postulate that the marine limit does not lie higher above the shell line than the depth of water indicated by the fossils as necessary for their growth. Such is the present vertical range of most of the species found in the Champlain valley—100 to 300 feet—that they do not furnish a criterion for discriminating between marine beaches and glacial

[1] Baldwin, S. P. 1894. *See* bibliography, 1.

lake beaches which latter there is reason to believe on other evidence lie within 300 feet of the upper limit of marine fossil shells.

When the beaches and bars of Lake Iroquois, a preglacial lake, are compared with the beaches of the marine district in the Champlain valley, the evidence is overwhelming that the lake beaches are much more strongly developed than those which may be ascribed to marine action in the latter field, the reason for this being that the lacustrine action continued at a given level for a greater length of time than did the marine waves. There is in short nothing in the local character of a lake beach to distinguish it from a marine beach. The geographic situation and the horizontal distribution of the beach phenomena on the other hand may furnish differentiae. Proglacial lake beaches run out against the glacier against whose front the waters are held up; in the opposite direction the beaches converge to one or more spillways whence the overflow discharged to the sea. Marine beaches and correlated shore phenomena develop about the entire periphery of an area of submergence, and phenomena of outflow are necessarily absent.

This criterion of continuity of beaches has been used in the present survey to distinguish the upper marine limit from earlier higher lacustrine shore lines which, as the evidence indicates, end abruptly as they are traced toward the Covey hill spur of the Adirondacks. In the district where these higher beaches, for which a proglacial lake origin is claimed, disappear, some phenomena demand further discussion in relation to the validity of the assumption made in this paper.

The water planes marked by deltas and beachlike deposits above 450 feet on the Mooers quadrangle, come at the international boundary to their northern limit indicating that the ice front impinged on the Covey hill spur and separated the waters on the east of the Adirondacks from those on the northwest. If it be supposed, however, that just previous to this stand of the ice the glacier had retreated, as it did later in the final liquefaction, far enough north to open free communication between the Champlain valley and the upper and lower St Lawrence (as Mr Upham has indeed supposed to have been for a time the case), then a beach or beaches would have been continuous about the spur only to be smoothed off and rearranged by the advance of the ice to the position to which the

beaches may now be traced. Such an oscillation of the ice margin as is here merely suggested, undoubtedly took place, and the possibility of it constitutes the weak point in the argument presented in this report in the attempt to fix the upper marine limit.

Such diffused shore lines might be expected to exhibit a trace in the waterworn character of the glacial drift along the belt in which the overridden shore lines were formed, in the case of a temporary and slight advance of the ice, one which, in this field need only have amounted to an oscillation of from 10 to 15 miles.

In this connection, it should be stated that certain peculiarities of the drift before referred to along the western border of the Mooers quadrangle from Deer Pond northward to the English river at Cannon Corners are not inconsistent with an advance of the ice such as is here considered possible. Waterworn drift varying from gravel to very coarse cobblestones with on the whole an unstratified structure and ice-swept contour covers the slope between the 700 and 800 foot lines quite above, however, the latest lake levels of this latitude.

These deposits lie, it should be noted, on the east of Blackman's rock, one of the large spillways of bare Potsdam sandstone, only the northern extremity of which appears on the map. It has seemed to me that the waterworn materials are to be ascribed to stream action contemporaneous with the position of the ice front along this line rather than to the involution in the drift of an earlier beach deposit formed at a higher stand of the sea than is advocated in this report. The fact that there are no clear traces of such smudged beaches around the Covey Hill slope has confirmed me in the belief that this objection to the accepted marine limit has in this case no clearly observed facts upon which to rest.

A second objection to the view that the higher beaches in the Champlain district are of lacustrine origin may be raised from the fact that along the slope of the Adirondacks the lowest shell-bearing layers of the marine series, as at Mooers on the Big Chazy, and Freydenburg's Mills on the Saranac, are found resting directly on the boulder clay without intervening nonfossiliferous beds or those bearing nonmarine fossils attributable to the deposits of a lake. The absence of lacustrine deposits in these two localities in the northern part of the area can

hardly be explained away by the supposition that during the lake stages the region where they occur was covered by the glacier so as to prevent deposition and that the ice retreated in such a way as, at once, to admit the marine fauna to the area, for when the ice front was as far south in the Champlain valley as the Saranac, it still had a long retreat to make before a passage would have been open through the Missisquoi region for the entrance of the sea with the Labradoran fauna. Before this could happen some nonmarine sediment most likely would have been deposited particularly near the mouths of streams, off which both of the localities here cited then lay. It seems more likely that this belt between 300 feet and 350 feet was so far from the lake shores as not to receive contributions of sand and gravel there being no tide to augment the offshore scouring, and that the clays were carried by the circulation of the waters to other parts of the lake floor.

Cut cliff in till near Port Kent. At only one point on the New York shore of Lake Champlain have I recognized what appears to be an old sea cliff entirely cut by waves. This cliff has been cut in a thick mass of till on the northwest flank of Trembleau mountain midway between Port Kent and Keeseville. The cliff may be seen at the old tollgate, now abandoned, on the direct road between the places named. The base of this cliff is practically at the level of one of the elevated stages of the delta of the Ausable river. According to the local contour of the United States Geological Survey atlas sheet the base of the cliff is about 330 feet above the present sea level.

The cliff is somewhat less than 100 feet high and extends for fully a third of a mile. It is a conspicuous object in the landscape from any point of view on the north and east because of the contrast of its somewhat ravined face with the smoothened or horizontally lined slopes which form its topographic setting.

I hold this to be a wave-cut rather than a stream-cut bank or cliff for the reason that the slopes of this mass of till, high above the cliff, exhibit numerous water levels showing that the ice sheet had retreated from this vicinity long before the cliff cutting began. It is to be presumed that this cliff was the work of waves during the marine invasion. Certainly those which acted on the higher parts of this till mass, either had no

such power as did the waves at the 330 foot level or if they had this strength they acted for a much shorter time at each level. It is to be presumed, when the mouths of the Champlain and the St Lawrence valleys were freed from the ice sheet, that the winds from the north and east would have had a greater fetch and that the glacial lake conditions of the higher water levels would be at once exchanged for more vigorous cliff cutting. It has therefore seemed to me highly probable that this cliff has its base approximately at the marine limit. There is another consideration which supports this view.

It is to be shown presently that the marine limit of this epoch is now tilted more steeply to the south than the shore lines of the earlier water-levels on the south. It appears to follow from the divergence of these ancient water planes, that before the marine invasion was established, the land was tilted down toward the north, thus determining the extent of the submergence; since then the land has risen. The marine action would undoubtedly be longer maintained at the level of the maximum of depression of the shore lines, for there the sinking land halted, reversed its movement and came up. Thus we ought to find, other opportunities being equal, rather decided evidences of wave action at this particular water level, for the land probably stood longer at the marine limit than at any other stage in its movement.

On the basal slopes of Trembleau mountain to the east of the cliff, are patches of beaches with well waterworn pebbles between the bare ledges at about the level of the base of the cliff above described.

There is also a very extensive development of the gravelly and sandy delta of the Ausable just below this level indicative of a longer stage of delta building than is found again below this level. If I am not mistaken Mr S. P. Baldwin has taken this delta to mean the same thing—the local index of the marine limit.

True proportions of the postglacial tilting of the upper marine limit. Lest the reader obtain from the diagrammatic profile of plate 28 an exaggerated idea of the steepness of the tilting of the old sea level in the Champlain valley, let him construct a straight line 1 mm thick having a length of 1196 mm. The thickness of this line will have the same proportion to the hight of

the uplifted seashore as the length of the line has to the extent of the old shore line above the present sea level within the limits of the State in a northsouth direction. Imagine a diagonal line passing from the top of the thickened black line on the right hand end to the bottom of the line on the left hand end. Then the inclination of this oblique line will slope at the same angle or rate a mile as does the upper marine limit of the Champlain submergence. The rate of rise of the upper marine limit is on this basis 4.411 feet to the mile to the north.

MARINE DEPOSITS OF THE CHAMPLAIN VALLEY

Lithologically the marine deposits of the Champlain valley are commonly referred to as clays but while this facies of the deposits is most striking in the vicinity of the lake, the area exhibits the normal threefold development of sediments under the transgression of the sea: viz, along the shore line, beaches and bars of pebbles and shingle together with stream deltas of sand; farther off, sandy bottoms; still farther from the shore line, clays.

In the case of the Champlain valley, the normal character of the three belts or zones of marine deposition is largely modified by the composition of the glacial drift previously laid down in the region. Each of the zones above named may exhibit boulders and coarse rubbly material. Furthermore, in the retreat of the sea or rather the rise of the land, each belt in turn has been passed over by the shore of the sea and the processes peculiar to the littoral zone have more or less strewn coarse waste over the sea bottom of the preceding stages. In general, however, there is a cobblestone, shingle, or pebbly zone on the foothills bordering the lake, a sandy zone over the flats at variable distances from the lake shore, and a clay zone adjacent to the lake. The zones are of very variable width on the New York side of the lake, all of them becoming narrower toward the southern contracted end of the present lake.

Out of the sandy and the clay zone rather characteristically rise older deposits of glacial till or gravels, which for a time existed in turn first as shoals and then as wave-washed isles in the receding sea. These hills have generally lost their original outline as drumlins or morainal mounds with kettles. At top a beach or bar has been heaped by waves and gravels and sands have been washed down the sloping sides, the finest sediments being strewn over the

surrounding flat as a shallow water sea bottom deposit. The hill, at least one slope of it, is frequently left strewn with boulders from the washing out of the material which could be more readily removed by the waves and currents. The annexed diagram showing the cross-section of one of these shoals north of Mooers Junction illustrates a typical case.

It is a noteworthy fact that in a few cases in this area, heavy beaches of rolled pebbles occasion the western flanks of these northsouth glacial hills, while on the eastern slope large boulders lie out on a surface which exhibits otherwise no marine action other than probable erosion. This peculiarity is brought out in the diagrammatic section given below.

Subdivision of the marine beds. The marine beds frequently exhibit in limited sections a passage from clays below through

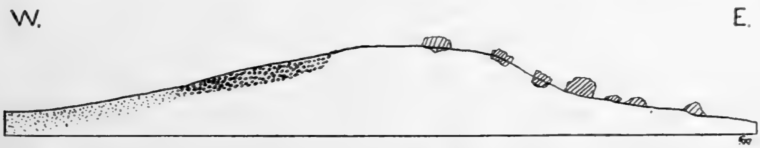


Fig. 24 Modified glacial hill with a beach. This hill has been successively a shoal and an islet

sands upward into gravels or even much coarser deposits. Particularly is this often the case in the sand zone. Nearer the present lake shore or on the inner borders of the clay zone sections reveal sands alone overlying clays. It is evident from the various sections and from the history of the changing sea level that the clays of the middle of the valley represent the deposits made there through the episode of marine invasion; that the lowest of these marine clays correspond in age to the highest marine beaches; that the highest of the clays correspond nearly to the lowest beaches now above the lake and clay levels. Pebble beds, gravels and sand, as well as clays must have been making during the entire epoch; it is therefore not feasible to establish time divisions on these lithologic characters. There is no such time division in the Champlain area as that of the Leda clay and the Saxicava sand but these biologic terms may be applied to facies of the deposits occurring in zones of more or less contemporaneous development.

DISTRIBUTION OF FOSSILS IN THE CHAMPLAIN DEPOSITS

The occurrence of marine fossils in the clays and sands of the New York Champlain beds has long been well known, but scant reference is made in the literature to their upper limits. In the course of the present survey search was made for fossils mainly within the zone of beaches above the zone of clays. In the following notes references are made also to the occurrence of fossil shells found on the northwest slope of the Adirondacks as far west as Ogdensburg. For the purpose of showing their bearing on the reconstruction of the upper marine limit in this region notice is also taken of certain shell-bearing localities in adjacent parts of Canada and Vermont.

As early as 1849 Prof. H. D. Rogers called attention to the fact that the then known shell localities in this geologic province indicated a want of parallelism between the water level of their epoch and that of the present seas. In recent years much more attention has been given to the evidence of warping of the earth's crust as shown by the deformation of traceable shore lines in the district of the great fresh-water lakes which came into existence with the withdrawal of the ice sheet. In a region like that of the upper St Lawrence and Champlain valleys, where beaches occur referable partly to lacustrine and partly to marine bodies of water, the evidence from fossil shells is of more than usual importance.

As having a slight bearing on the distribution of the marine fossils within the State, the occurrence of shells at Ogdensburg and Norwood is here recorded, but the discussion of the upper marine limit in that direction is withheld till a more complete examination of the district has been made.

Fossils at Ogdensburg. This locality has long been known. In 1903 Prof. A. P. Coleman collected Macoma groenlandica from the clays on the low ground in the southern limits of the city, and later in the same season both he and myself found abundant separated valves of the large Macoma calcarea with those of M. groenlandica and rarer Saxicava rugosa in stratified sands on the border of Ogdensburg and the town of Lisbon about ½ mile south of the St Lawrence at an elevation of about 281 feet above the sea. Professor Coleman

also found at this locality a single example of the gastropod Cylichna alba (?) apparently identical with the form now rarely found at Port Kent. The bivalve shells in this sand deposit invariably exhibited signs of transportation in that most of the detached valves were lying outside up in the sand layers after the manner of shells moved by rather gentle currents. Whether in their original matrix or not, the shells afford good evidence of the marine invasion to this point and to the altitude given.

Fossils at Norwood N. Y. Fossil shells of Macoma groenlandica are abundant in the clays at Norwood, St Lawrence co., N. Y., particularly in the low ground in the western part of the village. The sewer trenches opened in the summer of 1903 brought to light numerous pockets of these shells. I found this shell in clays under sands and lying on boulder clay about 3 feet below the surface near the street crossing the Rome, Watertown & Ogdensburg Railroad south of the Union station, at an elevation of about 335 feet. The same shell appears in the clays from the sewer trench on top of the hill in the northern part of the village at an elevation of 360 feet aneroid or 370 feet according to the engineer's levels compared with Norwood station. I also found Macoma groenlandica in a cutting of the Norwood & St Lawrence Railroad just northeast of the junction at Norwood at an elevation by aneroid of 350 feet. These shells were in stony clays, the rubbly marine drift, at the western base of the dune-capped hill which forms a prominent feature on the northeastern outskirts of Norwood. This region includes the highest shell locality yet discovered on the northwest slope of the Adirondacks and is, so far as I have been able to ascertain, the highest yet reported within the State. The locality is nearly 30 feet higher than the highest shell layer that I have seen in the Champlain valley but shells are to be expected in the western part of the town of Mooers as high as 400 feet.

Fossils at Montreal, Canada. The deposit of marine shells at the Côte des Neiges on Mt Royal is said to consist of a bed of gravel 6 feet thick with Saxicava rugosa and Macoma (Tellina) groenlandica. According to Sir Charles Lyell[1] the deposit is covered by an unstratified mass of boulders

[1] Lyell, Sir Charles. Travels in North America. N. Y. 1845. 2:119.

and gravel 12 feet thick. It is not altogether clear from the descriptions of this locality whether this overlying unstratified material is true till or a bed of coarse rubble washed down from the mountain side on the shell bed during the higher stand of the marine shore line at that place. It has apparently been assumed by Sir William Dawson and others that the shells pertain to the post-Wisconsin phase of depression. At the time of my visit in 1900 I was not, unaided, able to identify the locality. I have assumed in this paper, nevertheless, that the current view of the essential contemporaneity of the bed with other high level marine shells in the region is correct.

Fossils at Hemmingford, Quebec, Canada. Marine shells occur in Hemmingford, about 5 miles north of Mooers Junction, in a gravelly shoal on the southern margin of the village. A borrow pit in a pasture opened in 1903 afforded abundant shells of Saxicava rugosa in the attitude of growth in the openwork gravels at depths from 18 inches to 3 feet below the surface. The shells are large and strong and exhibit marked variations in form. From aneroid measurements, this locality appears to have an elevation of 257 feet. Saxicava also occurs in an old gravel pit on the west of the road at the same locality.

The freshness and strength of these shells at so slight a depth beneath the soil in gravels open to the free percolation of rain water is strong evidence against the supposition that the absence of marine shells in the sands and clays deposited about the margin of the retreating Wisconsin ice sheet along the sea border from New York eastward to the vicinity of Boston is to be explained by their removal in solution under the influence of meteoric waters following an uplift of that coast from beneath the sea.

Fossils near Mooers. The writer found marine shells on the south bank of the Great Chazy in 1903, at a point on the west side of the narrow neck of land in the sharp bend of the river ¾ mile above Thorn's corners.[1] The section there exposed shows about 10 feet of compact grayish sandy till resting on the Potsdam (?) sandstone. The surface of this till is planed off to a

[1] A picture of this locality is given by Cushing in the Annual Report of the State Geologist for 1895, pt 1, p.511, pl.III, Albany, 1896. The fossils occur at and above the dark line half way up the river bluff. Thorn (on the U. S. G. S. map) is given as Thom in the state reports.

level line of unconformable contact with overlying sands and clayey sands from 3 to 5 feet thick, in which near the base occur marine fossils. Overlying this bed are coarse waterworn gravels believed to be laid down by the river when its bed there was the top of the terrace now 340 feet above sea level. The following species were collected.

Macoma groenlandica....	rare	
Saxicava rugosa..........	dominant	
Leda arctica.............	not rare	
Yoldia (Portlandia) *sp*...	rare.......	J. W. Dawson. Canad. Ice Age. p. 241-2 Verrill. Invert. Anim. Vineyard Sound, p. 689
Balanus *sp.* fragments..	rare	

Saxicava rugosa, Leda, etc. are in the lower clayey bed usually intact and in the attitude of growth.

This locality is close to the 340 foot contour line of the United States Geological Survey map. Similar sands and clays are seen on the north side of the river below the bend at a point north of the camp meeting ground. The shell-bearing deposits are in strong contrast with the coarse wave and river strewn materials indicating the recession of the sea, and evidently pertain to the maximum marine stage following the disappearance of the ice from the locality. The smooth surface of the till on which the deposits rest and the apparent absence of beds referable to a lacustrine stage are rather characteristic of the marine series at this level from the Saranac northward. The same smoothness of the inclined surface of the till in the Saranac section at Freydenburg's Mills is noted below.

Fossils at Freydenburg's Mills on the Saranac. This locality, first noted, I believe, by Dr D. S. Kellogg and S. P. Baldwin, is one of the highest localities of marine shells on the New York side of the Champlain valley. The section as exposed in 1901 along the tracks of the Chateaugay Railroad reveals gravels and sands unconformably overlying the boulder clay. The till is a compact unstratified mass composed of bluish clay and clean, well striated boulders. No traces whatever were seen of the fossil shells in this lower glacial deposit. The surface of the till was

eroded and its trace in the vertical section was that of a smoothened plane dipping gently eastward toward the lake.

The shells occurred mainly at the base of the stratified deposit in sands resting directly on the till without trace of an intervening unfossiliferous bed such as might have been laid down on the till after the retreat of the ice sheet from the locality and the incoming of the sea. The upper part of the gravels appear to be of delta origin being on the whole coarser than the lower part of the water-laid deposit. The top of this deposit is over 340 feet according to aneroid measurements; and the fossil shells occur from near this level down the slope of the inclined bedding to perhaps 320 feet.

The following forms were collected, named in the order of their abundance: Saxicava rugosa, Macoma groenlandica, Balanus sp., Mytilus edulis.

Ries found Diatoms in the clay at Plattsburg. Shells and bones have also been reported at this lower level.

Fossils at Port Kent N. Y. One of the best known localities in New York for the occurrence of Champlain fossils is at Port Kent. Ebenezer Emmons[1] who gives two plates of fossil invertebrates found in the marine beds from various localities in northern New York, New England and Canada, states that he found the following list of species at Port Kent:

Tritonium anglicum	Tellina *sp.*
T. fornicatum	Tellina *sp.*
Mytilus edulis	Turritella
Pecten islandicus	Nucula portlandica
Mya truncata	Bulla
M. arenaria	

Sir Charles Lyell also gives an account of the shell locality at Port Kent. In a small brook south of the place (near the present railroad station) he observed at the bottom of the section: first, clay 30 feet thick with boulders; second, loam with shells 6 feet; third, sand, 20 feet thick. He found four species of shells: Mytilus edulis, Saxicava rugosa, Tellina groenlandica, and Balanus miser. He states that no shells were found at a greater hight than 40 feet above the lake (about 138 feet above sea level).

[1] Geol. N. Y. 2d Dist. 1842. p.128

I collected in the delta sands south of the railroad station at an altitude of about 155 feet above sea level rather abundant Macoma groenlandica, common Saxicava rugosa, a few Leda portlandica, fragments of a Balanus, two specimens of Cylichna alba (?). In the same horizon Mr P. T. Coolidge, of Watertown Mass., found in 1903 a fragmentary Mytilus edulis. At a lower horizon about 25 feet above the lake and 3 feet below the top of the clay Mr Coolidge found Mytilus edulis common, Macoma groenlandica rather common, and one specimen of Saxicava rugosa.

Mr Coolidge has also found shells in clay about 15 feet above the lake on the south side of the swamp 1 mile north of Port Kent. This locality afforded Saxicava rugosa common, Leda arctica and Macoma groenlandica, together with an undetermined lamellibranch.[1]

Fossils at Willsboro. Macoma groenlandica and Mytilus edulis were collected from the clays in the road gutter ¼ mile west of the railroad station, and south of the station at an elevation of about 220 feet above sea level. The bed of shells at this locality is 3 inches thick.

Fossils on Crown Point Peninsula. Macoma groenlandica was observed in the clays a few feet above the lake level on the west side of Crown Point fort ruins at an elevation of about 110 feet above sea level. This is the southermost point at which I have observed marine shells on the New York shore of Lake Champlain.

Marine shells on the Vermont shore. The Vermont geologists have reported a number of localities at which shells have been found in the clays in that state. The following abstract of the reported occurrences has been made with the view of comparing the elevation and southward extension with the occurrences known in New York.

According to the Vermont report of 1861, fossil marine shells were found at Swanton at an elevation of 140 feet; at Milton Falls, the highest locality, at 298 feet; at Colchester, at 320 feet;

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[1] While this report is passing through the press Mr Peet reports fossils at 300 feet elevation back of Port Douglas on the south of Trembleau mountain. Jour. Geol. 1904.

at Burlington at about 202 feet; at Charlotte, at 150 feet; at Panton, 320 feet.

Mr S. P. Baldwin in 1894 reported other occurrences as follows: at Vergennes at nearly 250 feet; from central Addison northward at almost any point less than 150 feet; at Shelburne Falls at 180 feet; in the northern part of Shelburne shells are reported as high up as 400 feet (?); in the delta of the Lamoille, shells in the vicinity of a terrace rising to 450 feet.

The localities at which shells have actually been observed by competent witnesses in Vermont agree very closely with the range of the highest localities in New York. A tilted plane standing at an elevation of 450 feet at the northern boundary of the state and meeting the surface of Lake Champlain at Whitehall would lie above the localities at which there is good evidence of marine shells. The apparent exceptions are both noted in Mr Baldwin's paper. First and most important is the reported occurrence of fossil shells by the Vermont Survey of 1861 in Elgin spring at Panton, at an elevation of 320 feet in the latitude of Essex N. Y. Messrs Baldwin and Richardson on visiting the locality state that they were unable to find any trace of the shells. If, as I understand it, the original report was based on shells believed to have been seen in a spring, little reliance could be placed on shells actually so found for the reason that the shells may have been washed out from the underlying loose sand and clay of the Pleistocene series and carried upward to the mouth of the spring, a position in which it is common to find rock particles swept upward from a depth. I have, in view of these considerations, been led to reject the Panton locality.

The second case is that of shells reported to Mr Baldwin at an elevation as high as 400 feet in the northern part of Shelburne. This locality appears from the evidence in New York to be too far south for shells at so high an elevation and as Mr Baldwin did not see them I am inclined to think he may have been misled, as I was early in my search for shells in this field, by descriptions well meant but totally misleading which I also was able to obtain from some of the inhabitants. One very promising case of shells having according to my informant all the characters of a Macoma of some sort turned out on going with him

to the locality to be nothing more than conchoidal fracture chips from the checking of the clay as it dried in the sun. Small concretions have also been found to constitute the basis of an informant's description of fossil shells. If I understand Mr Baldwin's interpretation of the marine limit in the Champlain district he also considered the two localities above mentioned as negligible.

Ebenezer Emmons[1] states that two fossils shells, including Saxicava rugosa, are found the entire length of Lake Champlain, but he cites no locality south of the southermost named in this report nor have I been able to get a record of any such southern extension of the fauna.

Depth of the submergence indicated by fossils. The bottom of the sea within the reach of continental deposits is a surface sloping from the shore out into deep water, and is normally divided into a zone of pebbly and sandy deposits at the shore, a zone of sandy deposits farther out, and still farther out a zone of clay. The pebble and sand zone is the littoral belt; in tidal seas, bared at intervals to the atmosphere. The sand zone proper is in shallow water; the clay zone extends from the sand zone out into deep water. Each zone of bottom varying thus in its lithologic character differs also in its depth of water and consequently the pressure and temperature of the water and thus each zone becomes the abode of different animals. The marine shells found in the clays and sandy clays of the uplifted sea bottom in the St Lawrence and Champlain valleys are, according to Sir William Dawson, like if not identical with those of species now living in the lower St Lawrence river and gulf at depths less than 100 fathoms. The beaches of the sea in which the marine shells in the Champlain valley lived should not then occur more than 600 feet above the shells. Sir J. W. Dawson regarded the fauna at Beauport, Quebec, as living in from 100 to 300 feet of water. The species found there include most of those known in the Champlain valley. Evidences of water levels exist in the Champlain area between 600 and 700 feet above the present sea level. As shown in the diagram [pl. 28] the known localties of marine shells ranging as high from 540

[1] Geol. N. Y. 2d Dist. 1842. p.283–85.

to 560 feet on Mt Royal at Montreal, are found at successively lower levels in the Champlain valley, and the upper limit at which shells have so far actually been found passes below the level of Lake Champlain at Ticonderoga.

All the beaches whether marine or lacustrine in the Champlain district on the New York shore occur therefore within the range of possible marine surfaces as indicated by the fossils. The fossils alone do not therefore suffice to fix any one of the levels as the upper marine limit. Independent evidence must be advanced to show what and how many of the higher beaches were like those of Lake Iroquois, on the west of the Adirondacks, formed in an ice-dammed lake.

A comparison of the line, drawn through the highest known localities of marine shells at the eastern base of the Adirondacks, with the line showing the upper marine limit in that field shows that the fauna composed of Saxicava rugosa, Macoma groenlandica, Mytilus edulis, and a species of Balanus falls off in elevation toward the south at practically the same rate as the phenomena which are taken to indicate the highest stand of the ocean waters. As sea level, during the uplift of the land, stood in succession at all points below the upper marine limit, it is not always possible to determine the relation of the sea to the land when any particular deposit of shells was made; but if this upper range of shells in this district affords any ground for an assumption as to the upper marine limit in the inland waters on the north side of the Adirondacks it is to be presumed that there also the upper marine limit will be found closely coinciding with the highest shell deposits when these have been more fully ascertained.

NOMENCLATURE OF THE MARINE DEPOSITS

Each generation of men as it comes into possession of its inheritance of facts and theories in any department of science and gains knowledge of its own, finds something unsuitable in the names applicable to views and bodies of fact whose limits and relations have in their hands come to be notably changed. In the course of the collection and comparison of data centering about some early observed phenomenon the name of the type

thing becomes gradually extended in a generic sense to phenomena which in the later stage of critical classification appears to have been given too extended a meaning, if it has not in a premature broad generalization been made to embrace phenomena which in the later stage of critical classification appertain to a different system of distribution in time and space. Quite often, owing to the limits placed on the choice of terms, it is discovered that the name itself has been preoccupied by use for a very different object. In short the history of many scientific names is somewhat as follows.

In the so called natural history sciences names are first given with the purpose of defining exactly some object, be it fish, plant, land form or terrane. Being the type of its kind, similar objects having some essential likeness, structure, form, mode or time of occurrence are grouped with it under the same name. As nature in her prodigality never exactly reproduces her creations, some of the objects present differences of one sort, some of another, so that the name inevitably comes to have a broadened and weakened meaning in proportion to the number of occurrences which it is construed to designate. In time it thus loses its original definite meaning and being replaced here and there by terms of more accurate definition falls gradually into disuse. Its friends may endeavor to save it either in its original sense or with a restricted meaning in some respects different from its original use; but it has now lost its chief value as a scientific name since it is ever a source of confusion to the reader who has to carry in his mind, if he knows his subject, the fluctuating values of the word in the different periods of its history. In all this, scientific terms but exemplify those laws of use and disuse to which any words of the language are subject. The names which have been introduced for the fossiliferous marine deposits described in this report appear at present to be under the operation of these laws. The term "Albany Clays" specifically applied to the glacial rock-flours of the Hudson valley north and south of Albany in 1846 antedates the name Albany since given by Texan geologists to certain carboniferous beds in Texas.

In 1850, Desor[1] gave some account of the fossiliferous clays and sands of the St Lawrence valley and very appropriately called them Lawrentian. They constitute the only example of a geologic formation whose principal and most typical area lies within the basin of this majestic river. Only one other name is so suggestive of their distribution, that of Quebec in which province they chiefly lie.

In 1853, Logan unfortunately employed practically the same name in the term Laurentian in the official reports of the geological survey of Canada for a group of rocks believed to be at the base of the geologic column, and Desor's proposal failed of adoption despite the claim for priority which might have been made for it. In fact Desor's term appears to have been overlooked till the Vermont geologists came to decide on a name for the marine deposits of recent date within the area of that state, when it appears a second unfortunate choice attended the naming of these ill appreciated marine deposits.

In the *Report on the Geology of Vermont* by Edward and Charles Hitchcock and Hagar the term Champlain clays was adopted to designate the marine fossiliferous beds along the Vermont shore of Lake Champlain, the name being proposed in part for the reason as stated that Desor's prior term had been appropriated and was in established use for rocks of a very different age. In this connection the belief was held that the term *Champlain group* introduced into the New York reports by E. Emmons in 1841 had fallen into disuse, a condition in which the term has certainly been up to its proposed revival by Clarke and Schuchert in 1899.

In the employment of the term Champlain by the Vermont geologists in 1861 its meaning was made sufficiently clear as applying to the marine beds which there followed the glacial drift, though the formational term *clays* seems rather to parallel it with the biologic term Leda clay proposed by J. W. Dawson in 1857, neither term being strictly applicable to the entire series of deposits laid down under this marine invasion, a fact which was partially recognized in Canada by the use of the term Saxicava sand in the same year. The term Champlain having been

[1] Bost. Soc. Nat. Hist. Proc. 1850. 3:357–58.

thus newly defined, during the slumbers of the Silurian sense of the name, quickly passed in American geologic literature into an astonishing breadth of meaning and usage as wide as the continent itself and was stretched to embrace deposits laid down before, during and after the peculiar drift deposits from which in the Vermont report of 1861 the Champlain clays were accurately discriminated as the result of a definite process acting at a subsequent time. Whatever confusion may be attributed to the application of the term Champlain to the postglacial marine deposits of the northeastern part of America by the Vermont geologists it is clear that the original account did not contemplate the inclusion under this term of practically all the Postpliocene stratified sands and clays in other parts of the continent. This most extended use of the term is found most clearly set forth in the third edition of Dana's *Manual of Geology* of 1880.

The advances made in the past two decades in the separation of the glacial drift into distinct epochs of ice advance and the introduction of such a term as Wisconsin for the last series of ice sheet deposits has tended among other causes to leave the term Champlain as employed in Dana's *Manual* a synonym for an ill assorted and broken up collection of facts, there remaining only for its exclusive use the original marine beds of the Champlain and St Lawrence valleys and their equivalents elsewhere, for which the term was originally proposed by the Vermont geologists. In this restricted sense for which a name is and ever must be needed the name would be appropriate did it not find itself confronted with a contest for survival by the resurrected Champlain group of the lower Silurian whose title to recognition according to the law of priority which should govern all scientific names is clear but whose rehabilitation must nevertheless, in view of the circumstances above detailed prove a source of confusion. In fact to continue the use of either term from now on is to involve any context in which they are introduced in some obscurity. The happiest solution of the difficulty presented by the present status in geology of the name Champlain would appear to be to allow both applications with whatever postfixes to become obsolete in geologic literature. The name of Samuel de Champlain as much as we admire his high character

and valorous exploits is sufficiently memorialized in American geography by the beautiful lake which bears it, without his patronymic being seized on as the designative of geologic events of which he must have been ignorant.

The ancient name of Lake Champlain, Lake of the Iroquois,[1] has in recent years been applied to the great ice-dammed glacial lake which in the Ontario basin preceded the marine invasion. The name Quebec now obsolete and replaced by standard names is still retained by the Canadian geologists as a local designative; its use in Pleistocene geology would be ill advised on account of the history of the term as recorded in the literature of North American geology. The only safe course, it would therefore seem, is to propose the adoption of a name free from the entanglements of meaning and the confusion which surround the names Champlain, Quebec and Laurentian. The best studied section of these marine fossiliferous beds is that of Montreal, the ancient site of which city was occupied by the Indian settlement of Hochelaga. It is therefore proposed to call the deposits of this marine invasion the Hochelagan formation and the subepoch or stage of their time of deposition as the Hochelagan, a phase which follows the Wisconsin with its late lacustrine stages contemporaneous with the departing ice sheet.

HISTORY OF OPINION CONCERNING THE SOUTHERN EXTENSION OF THE MARINE CONDITIONS

Once the marine origin of the fossiliferous clays in the Champlain valley was recognized, the difficulty of separating these deposits from other similar materials naturally led to the conclusion that the marine waters passed through one or more of the narrow straits separating the Champlain from the Hudson valley and thence continued to the ocean on the south. The following writings and their dates are given only as an illustration of the history of ideas. The latter two by Upham and Baldwin anticipate the present report.

The views of the earlier Vermont geologists concerning the southward extension of the marine invasion is expressed in a

[1] The Indian name of Lake Champlain is stated to have been Caniaderi-Guarûnte. Kanyatare is Mohawk for lake. Doc. Hist. of State of N. Y. 1850. 3:1190.

geological textbook by Alonzo Gray and C. B. Adams.[1] The submergence indicated by the fossiliferous clays in the valley of Lake Champlain was placed at 400 feet above the present sea level. New England and New Brunswick are regarded as having then formed a large island, separated from the mainland of New York by a strait, "which extended from the valley of the St Lawrence through the valley of Lake Champlain, of the Champlain canal and of the Hudson river. The summit level of the canal indicates the most shallow part of this strait which had a depth of about 125 feet."

Ebenezer Emmons[2] speaks of the "clays of Champlain and Albany" as marine and of the "connection by water of the Gulf of St Lawrence and the bay of New York." "New England and a part of New York were an island separated from the central part of New York by a narrow strait."

Mr Upham[3] in 1892 advanced the idea that at the close of the last glacial epoch the Hudson valley formed a glacial lake bounded on the north by the barrier of the ice sheet during the retreat from the basin of Lake Champlain and the St Lawrence valley. The barrier of this lake on the south was thought to have been due to an elevation of the present mouth of the Hudson which afterward sank beneath sea level. The subsidence of this coast is still going on, and the submerged channel of the Hudson has been mapped by the United States Coast and Geodetic Survey. The absence of marine fossils from the postglacial beds of the Hudson valley is taken as evidence that this valley has not been occupied by the sea either as an estuary or a strait at higher levels than the present since the ice age.

DeGeer[4] believed that the Catskill delta was formed at a time when New England and the contiguous portions of Canada were made an island by a strait on the west and the enlarged gulf on the north.

From a rapid review of several localities he constructed a chart of isobases of equal change of level. In the Hudson and Cham-

[1] Gray, Alonzo & Adams, C. B. Elements of Geology. N. Y. 1853. p.160–61.

[2] Manual of Geology. Phila. 1860. p.247–48.

[3] Bost. Soc. Nat. Hist. Proc. 1892. 25:335.

[4] Bost. Soc. Nat. Hist. Proc. 1892. 25:335.

plain valleys he placed the 0 isobase at New York and that of 600 feet elevation near Plattsburg.

Mr S. P. Baldwin in 1894[1] regarded the heavier sand deltas of the rivers tributary to Lake Champlain as the shore equivalent of the deep water clays with marine fossils and hence as marking the limit of salt-water invasion. In his opinion the sea did not reach higher than 150 feet at Whitehall and was 500 feet at St Albans in Vermont, giving a postglacial tilting of the land at the rate of 3 feet to the mile.

The higher beaches, 658 feet at St Albans as noted by De Geer, are described as slight and regarded as due to a glacial lake held in by the concave front of the retreating ice sheet. This lake it was believed penetrated into the Hudson valley through the Whitehall-Fort Ann valley.

[1] Pleistocene History of the Champlain Valley. Am. Geol. 1894. 13:170-84; map pl. 5, at p.170.

Chapter 11

COMPARISONS AND CONCLUSIONS

In the foregoing chapters the local history of the retreat of the ice through the Hudson and Champlain valleys has been presented in its general outlines, with its accompaniment of proglacial lakes of ever increasing length, finally giving way to the invasion of the sea over the Champlain district. It remains to compare certain phases of this history with reference to related data before proceeding to the drawing of such conclusions as appear tenable.

COMPARISON OF THE WATER LEVELS OF THE CHAMPLAIN AND HUDSON VALLEYS

The difference in the aspect of the surface deposits of the Champlain and lower Hudson districts is so great when viewed in the light of a critical diagnosis of glacial and marine phenomena that I am sure one coming from the easily recognized shore line and sea bottom phenomena of the Champlain valley to the mouth of the Hudson would find no equivalent indication of submergence in that district other than that which now appears to be in progress. All of the evidence in the lower Hudson appears to me permissive of a much higher stand of the land thereabouts during and since the retreat of the Wisconsin ice sheet began. But one serious point of difference which has been much discussed by Dr Merrill and myself concerns certain fine silty sands which occasion the tops of bluffs near the Hudson river, ranging in altitude up to 200 feet at least. It has seemed possible that some of this material may have been laid down over the district during a time of late submergence. In such places as I have examined the deposits or where they were examined in company with Dr Merrill, they seemed to me to be involved in the ice-laid drift in such a manner as to indicate their contemporaneity with the melting of the ice sheet in the southern Hudson valley and I have, rightly or wrongly, considered the evidence of the proglacial deltas and terraces with their ice contact borders and their exemption from overlying clays and marks of erosion by standing water as weighing more strongly in favor of the nonsubmergence of this

area since the hight and during the retreat of the Wisconsin ice sheet.

I have elsewhere commented on the difference in the inclination of the water levels in the lower Hudson and the Champlain valleys. The diagram, plate 28, has been prepared to spread before the eye some of the details bearing on this generalization. A particular explanation of the diagram will be found at page 254. In this graphic interpretation of the ancient water levels it will be seen that those of the lower Hudson are made to incline at about one half the angle of those over the Champlain valley. It would be a very hasty conclusion to infer without particular facts to support the view that this difference of rate of inclination is simply due to a more rapid rise of the land on the north. These evidences of water level cover a period as long as the entire retreat of the ice sheet, a time as yet of unknown duration but presumably measured by tens of thousands of years so that there has thus been time for many changes of level.

The terraces of the Hudson are too discontinuous and unrelated within short distances to draw very certain conclusions from their levels particularly in the district from the Highland canyon northward to the beginning of the Albany clay cover on the rock terraces. In the diagram, plate 28, I have compared the proglacial delta levels with the line A-B. This line accords well with the rise in level of these deposits toward the north till the vicinity of Newburg when great irregularity appears in terrace levels most of which bear the signs of deposition in the presence of the retreating ice tongue in the Hudson valley. Not only these latter but also those on the south which appear to decrease southward in elevation at a regular rate as indicated by the line A-B might plausibly be interpreted as made in a succession of water levels essentially parallel with the steeper inclined water planes over the Champlain district. In this view it is necessary to regard the entire eastern part of the State tilted to the north to such a degree that the line L–M on plate 28 is at sea level or parallel to sea level, and to regard the waters from the ice front at all stages of retreat as discharging through the Narrows in a some-

what regularly deepened channel excavated in the drift filling of the older rock gorge of the Hudson which it is to be presumed was quite as deeply filled when the ice began to retreat as it now is. The most serious objection which I have to this view is that it makes it necessary to suppose that the land remained at practically the same level throughout the epoch of retreat and till the beginning of the marine invasion on the north. If we accept, as on the whole seems necessary, the successive deltas rising to the north from near the Narrows to beyond the Highlands as indicating the actual water level within the valley during that portion of the ice retreat, then two alternative hypotheses present themselves to account for the difference of inclination of the earlier and later levels in the lower Hudson and Champlain valleys respectively. The first of these, the simple one, attempts to explain the difference of inclination by a more rapid rise on the north, not excluding, what the observed facts demonstrate, some depression on the south. Here again the fact that the attempt is made to compare the levels of water bodies which existed at very different times leaves the matter in doubt. The second of these hypotheses is that after the retreat had gone on with bodies of water standing in front of the ice with their levels approximately parallel owing to the stability of the land as regards tilting, the whole eastern part of the State became tilted down toward the north during the stage of Lake Vermont, and that in the subsequent reversal of this movement the same district participated blocklike in the change. There are no facts indicating precisely how far above sea level any part of the district lay, till the upper marine limit was established. For, though we may determine the rate of tilting by a change of the former sea level, it is obvious that the whole mass may have been undergoing a positive or negative movement at the same time that it was tilting.

The district shows a number of features which are better explained by this hypothesis than by the other view. In the first place, the Albany clays sheet the rock terraces of the middle and upper Hudson valley but are wanting over the Highland and southern section, their lithologic equivalents being there

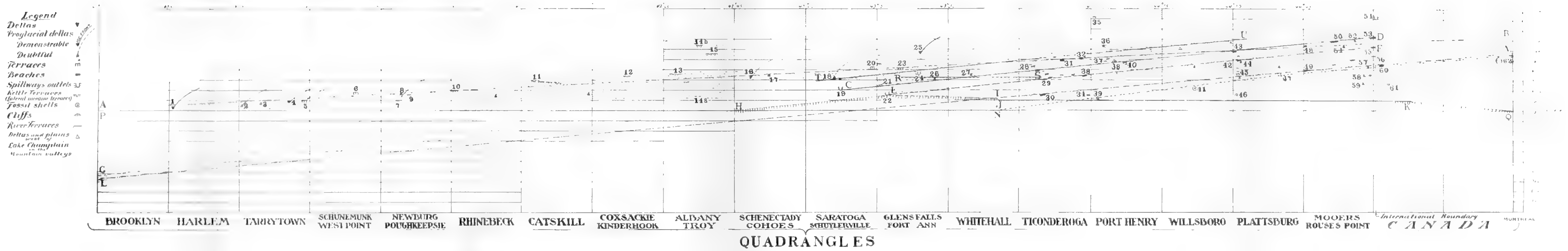
found in earlier proglacial clays. The water body in which the Albany clays were formed appears to have spread over the rock terraces and across the middle Hudson valley at a time when the region on the south rose above the water level, confining the waters to the excurrent stream lying within the gorge. The land must have been tilted to the north in comparison with its present attitude to have brought about such a distribution of effects. The well known phenomena of the submarine Hudson require also to be explained. While it is difficult to determine at what precise epoch the erosion phenomena there presented had their origin, the theory of high elevation on the south at this time is rendered permissive by the knowledge we have of the old channel.

DISTRIBUTION OF KETTLE HOLES MARGINAL TO THE HUDSON AND CHAMPLAIN VALLEYS

The accompanying plate [pl.28] represents the position and altitude of the kettle holes in the gravels and sands marginal to the Hudson river and the New York side of Lake Champlain. Some of these kettles, as on the Brooklyn sheet are in moraines, but most of them are in plains of gravel and sand marginal to masses of ice which lay at one stage or another in the valley. Excepting the type of kettle which occurs in the Brooklyn moraine, those northward along the Hudson and Champlain invariably represent the melting out of detached or buried blocks of ice from local deposits of gravel and sand which were at their time undoubtedly above sea level and presumably, on account of the barrier which the ice of their margin imposed, in an embarrassed drainage and hence above the level of standing waters farther along in the drainage system toward the sea on the south.

Such of these shallow depressions as came within the reach of the clay-bearing waters or later deposits of gravel and sand would have been buried. Thus it is strongly probable that the lower limit of kame kettles in the Hudson and Champlain valley lies at or above the upper limit of local submergence whether by long continued glacial lakes or the incursion of the sea. The lines representing on one hand the lower limit of kettles and on the other the upper limit of standing bodies of water should roughly corre-

PRELIMINARY PROFILE OF WATER-LEVELS FROM NEW YORK NARROWS TO MONTREAL



spond. It is to be anticipated, however, that the kettle phenomena should be very irregularly spaced from north and south and more likely to be found in areas of frontal or strong marginal ice drainage than elsewhere.

Furthermore there may be more than one line of pitted plains and terraces at varying distances and elevations from the main drainage channel as has been explained in the preliminary account of glacial drainage.

The plotting of the known kettles gives an example in the moraine at Brooklyn at about 100 feet; some at the foot of Crow's Nest Mountain at 160 feet; and other shallow pits south of Poughkeepsie near Mine Point at about 170 feet, all of which fall fairly closely into a southward tilted plane, and all three lying above the water levels in that part of the Hudson river valley.

North of the above described kettles on the Rhinebeck sheet and the southern part of the Catskill sheet are small groups of high lying kettle deposits, probably marking earlier marginal deposits than those nearer the river when the Hudson river glacier had shrunk to smaller dimensions. The lowest of these depressions inclosed by the 240 foot contour near Elizaville overlooks a flat of water-laid deposits at about the upper limit of signs of standing water after the disappearance of the ice from this part of the valley.

On the whole the kettle holes on the Rhinebeck and the southern third of the Catskill sheet are above the general level, and those on the north and south are much above the levels marked by terraces or deltas indicating open, standing water.

Very few kettles obtrude themselves on our notice in going north to the southern part of the Troy and Albany sheets. Excepting one low kettle on the Troy sheet near Teller hill at 240 feet, the kettles from near Albany southward to the middle of the Catskill sheet fall along a tilted line which is about one half that of the tilt of the upper marine limit in the Champlain district. The actual tilt is at the rate of 2.8 feet a mile for about 50 miles.

Here again comes a decided break in the kame kettle deposits. From the northern middle portion of the Troy sheet to the northern part of the Schuylerville, there are none of these signs of deposition in the presence of ice near the Hudson river at levels

below 500 feet, but a number occur east of Troy between 500 and 720 feet, and one group on the Cohoes sheet at 600 feet. On the northern part of the Schuylerville sheet, kettle holes come in again at 360 feet near Moreau pond; and examples may be encountered along the rising profile line to the north on the Glens Falls sheet in the Glen lake district with inclosing contours at 420 feet, and still farther north on the Ticonderoga sheet at Street Road with inclosing contours at 540 feet. This line of kettle deposits rises northward at the rate of 3.2 feet a mile, or more steeply than the earlier ones on the south.

Comparing these three segments of lowest lines of kettle holes in the Hudson-Champlain trough, we observe that each going northward represents a successive later stage of the ice retreat, that each profile line on the north is successively more steeply tilted southward, and that these lines lie slightly oblique to a general line of tilted levels which may be drawn from the international boundary on the north to New York Narrows on the south.

It is reasonable to suppose that this increase in the tilt rate toward the north is not an original feature but depends on a change which has taken place in the attitude of the land, a change which is demonstrated as being a tilt in the same direction by an abundance of facts drawn from other kinds of evidence. It is furthermore probable therefore that each of these segments of kettles in tilted profile lines was more nearly horizonital originally than now and that the steepest of them was as flat as is now the least inclined. If this be true it follows that the degree of tilting increases northward from New York Narrows to Lake Champlain.

EVIDENCE FROM POTHOLES NEAR THE HUDSON GORGE

Glacial potholes, the so called giant kettles, are of value in determining the relation of land and sea when they occur in abandoned water ways or localities where glacial streams can be shown to have been the cause of their making. A number of localities of potholes have been described. A pair of these water-worn holes may be seen in the rocks at Wappinger Falls at an elevation of about 45 feet above sea level. Professor Osborn has described a glacial pothole near Catskill N. Y. N. L. Britton noticed large ones near Williamsbridge. O. P. Hubbard has described potholes opposite Catskill near the Hudson. Those on the

Mohawk above Cohoes have been measured and described by Mr Gilbert. Fitch mentions potholes on both sides of Wood creek in the gneiss and sandstone at various hights, one of them lying 60 feet above the canal. Some of these potholes are undoubtedly now in process of formation. No attempt has been made in this survey to determine the value of the known potholes in the eastern part of the State as indications of the relation to sea level during the time the ice was on the country. So far as those which have been described are concerned and are of glacial origin, they would apparently admit of the land being somewhat lower than it now is or indefinitely higher.

EVIDENCE OF HIGHER ELEVATION OF THE LAND IN THE SOUTHERN HUDSON VALLEY

Distinct evidence of a higher stand of the land in the middle and lower Hudson valley and over the submerged continental shelf is found in several kinds of facts.

The submarine valley already referred to as extending the Hudson seaward has often been appealed to as evidence of elevation during the glacial period. The channel probably means elevation at so late a time but no one has been able as yet to determine the precise epoch in the glacial period from any evidence the channel affords as to when the Hudson coursed through it. The existence of the channel is however permissive of elevation at any time during the Wisconsin epoch, and appears to the writer to be favorable to the view maintained in this paper.

Of the particular evidences found within the existing land area, the drowned Hudson gorge, the drowned mouths of its tributary streams, and the abundant evidence about the mouth of the river that the coast is now and has been sinking in relation to sea level are much better evidence of a higher stand of the land during the waning Wisconsin epoch than the submerged Hudson channel taken alone. Some of these more definitely timed indications of depression are described in the following notes.

In the southern Hudson valley the present is a time of relative depression following one of uplift of the land to a higher level than the present. That the land is undergoing or has recently undergone a change of level in the lower Hudson valley is shown by the character of many lateral stream valleys.

Thus the Croton river entering the Hudson on the east through a valley excavated before the Wisconsin epoch has a relatively broad mouth and is evidently engaged in silting up Croton bay, but previous to this existing stage and subsequent to the deposition of Croton point delta at that stage of the ice retreat there took place extensive alterations in the outline of that deposit through erosion along the present path of discharge of Croton river into Tappan sea. There is also the deep cut which divides Croton point delta into two parts now loosely tied together by beaches and swamps.

Cedar pond brook at Stony Point presents something of the same evidence. It has cut deeply through the North Haverstraw terrace which it built against the ice margin, as soon as the retreat of the glacier admitted of discharge into the gorge, but in its earlier excavatory work cleared away the bed below the present sea level, forming the back bay behind Grassy point which in the present stage has become partly filled with alluvium and swamp growth.

Peekskill cove might be cited as an analogous instance of depression in progress but there are reasons which have been set forth above for considering this as originally unfilled, the terraces being marginal to ice in the channel. The continuance of the cove as a small harbor, however, is dependent on the depression, for the streams which enter it are of considerable length and have no appreciable delta.

Popolopen creek on the south of the site of Fort Montgomery is another cove which seemingly should have been filled at least to the present water level were not the land now lower than it was at some epoch after the retreat of the ice sheet.

Likewise Fishkill creek enters the Hudson through an opening, now marsh filled, indicating considerable excavation below the present level of the sea before the actual water level was attained by the deposition of alluvium.

Wappinger creek, below the falls, is a drowned valley without a delta.

Rondout creek, coming in from the west and loaded with sediment, has evidently in recent times filled up a broader channel which demands considerable excavation below the present sea level at some epoch after the retreat of the ice.

Esopus creek, draining the southern field of the Albany clays, shows less signs of this change of level, and its delta is one of the marked recent alluviums of the Hudson river.

On the other hand Roeliff Jansen kill, which comes in from the southeast and enters the Hudson below Catskill from a region of clays and, higher up, sands, has a broad reentrant mouth, showing excavation at a preceding stage.

The Catskill is a large stream with a narrow gorgelike mouth in the clay terrace and possibly is not on its original path where it joins the Hudson.

Stockport creek is another broad creek valley now largely silted up but indicating broad erosion below the present sea level, subsequent to the deposition of the Albany clays.

From the mouth of Patroon's creek at Albany 42° 40′ north latitude, the relation of side streams to the Hudson gorge changes and above that point in the river the tributary streams have prolonged courses over the bed of the old channel. Lateral embayment of the mouths of these streams no longer takes place, and evidence of uplift or of excavation of the river bottom everywhere manifests itself in the rock floor of the ancient gorge by the behavior of the main stream and its tributaries.

If the northern Hudson valley is or has been rising and the southern part of the valley is or has been sinking, somewhere between the two areas must lie a line of no change of level. It has already been noted that a marked change in the character of the side streams in their relation to the gorge and its fiorded waters takes place at Albany which is near the head of tide. The actual delta of the Hudson river, as pointed out by Hayden[1] as early as 1820, occurs in this part of the river extending from near Albany southward probably as far as Coxsackie in the form of alluvial islands and shoals with ever increasing swampy mud flats.

It is presumable that the axis of rotation in the uplift of this region coincides with the present head of the delta or the vicinity of Albany, for, if this axis lay to the south of this point, marks of uplift in the side streams should appear farther south than they do and, if the axis lay to the northward at an appreciable distance, marks of depression in the mouths of side streams should manifest themselves instead of the signs of apparent uplift.

[1] H. H. Hayden in Geological Essays. Baltimore. 1820. p.35.

POSSIBLE OBJECTIONS TO THE ELEVATION THEORY

The view presented in this report that the land was for a part of the time during the retreat of the ice and at the time of the maximum submergence on the north several hundred feet higher than now at the mouth of the Hudson is, I am aware, in distinct opposition to the views held by some geologists and it seems necessary in this connection to meet the objections which may be raised so far as is permissible by the evidence now at hand. It should be borne in mind however that the time since the ice began to retreat is relatively long when compared with the time taken for such changes of level as are admitted by all in the St Lawrence district and that it may be that what at first is regarded as contradictory evidence of elevation and subsidence about the mouth of the Hudson river is but proof of movements which have succeeded each other.

Early in the field work on which this report is based it seemed to me probable that the land about New York city had not undergone since the ice began to retreat, a notable change of level either of uplift or depression and after examining the typical marine deposits and shore lines of the Champlain district it became evident that no recent marine deposit had been seen by myself or convincingly described by others above the most recent beaches in that southern field. I believe that one who has had the opportunity of studying attentively the Champlain marine district will be compelled to abandon the view of a postglacial submergence within the field of the Wisconsin drift sheet about New York city other than that now in progress.

The most positive statement which the elevation theory has to meet is the supposition of Professor Salisbury,[1] that the gravels of the Far Rockaway ridge on Long Island are a marine shallow water deposit of a date as late as the ice retreat, and the statement that they are regarded by him as the local equivalent of his Cape May formation in Southern New Jersey. From a reconnaissance of the area on Long Island I had about the same

[1] Salisbury, R. D. in Geologic Atlas of the United States, New York City Folio, no. 83. 1902. p.15, 16; *also* Surficial Geology Sheet of the Brooklyn Quadrangle, where the Far Rockaway deposit is given as "gravel and sand of marine shallow water origin."

time also referred the deposit to a nonglacial origin[1] but supposed it to be Prepleistocene because it was overlain about its base by the outwash plain of the Wisconsin moraines, and because I then saw no feldspathic pebbles which are so characteristic of glacially derived materials in this field. In revisiting the ridge with Messrs Fuller and Veatch in the spring of 1903, they pointed out a considerable percentage of compound gravels in the deposit allying it with the Pleistocene deposits, in referring it to which I fully concur with them. These authors regard the deposit as an outlier of the Manhasset,[2] a deposit of glacial origin containing much locally derived material and as I think all are agreed, deposited during a time of submergence. The deposit at Far Rockaway therefore has no bearing on the question of the attitude of the land during the late Wisconsin ice retreat; and if the Far Rockaway gravels and the Manhasset formation are the equivalent of the Cape May formation this last named with its signs of depression of the land in southern New Jersey must be contemporaneous not with the Wisconsin ice epoch but probably with the next preceding glacial advance or the Iowan.

It may be urged that if, at any time during the retreat of the ice, the land was raised several hundred (say 700) feet above sea level south of the Highlands, the Hudson gorge should there now be deeper, in the manner of the Norwegian fiord. In the absence of borings in the bed of the Hudson river we are in ignorance of the depth to bed rock in the deepest part of the buried channel. However deep the filling may be, undoubtedly a great amount of filling has been washed in from the clayey banks and the upper Hudson gorge which has been reexcavated in its clay filling. Since the deposition of the Albany clays something like 8 cubic miles of clay and coarser sediment have been removed from the old gorge between say Kingston and Fort Edward. If we suppose this sediment to have found its way to the bottom of the river between Peekskill and the Narrows, a distance of 65 miles, this supply of silt and clay alone would fill

[1] Woodworth, J. B. N. Y. State Mus. Bul. 48. 1901. p.651, also map pl. 1.

[2] Fuller, M. L. & Veatch, A. C. Results of the Resurvey of Long Island, New York. Science. 1903. 18:730.

a trench of that length 1 mile wide and 660 feet deep. Of course such an arithmetical calculation is solely intended to show that enough material has been transferred in the Hudson valley since the glacial period to more than fill to its present state an old gorge such as the elevation hypothesis supposes to have existed.

As we have no direct evidence that the Hudson gorge is so deeply excavated in the bed rock from West Point southward through the New York Narrows the question of altitude of the outlet at this particular stage under the conditions assumed must remain locally undetermined.

The width of the Narrows at the present sea level is approximately 1 mile and the banks are glacial materials. There is naught in the deposits at the Narrows to render a former deeper channel impossible. In fact, if we suppose the sides of the channel where it is narrowest to slope down at an angle no steeper than 30 degrees the slopes would meet at a depth of over 1500 feet below the present sea level, a depth much in excess of any required depth of the Hudson channel for the drainage of waters from the Hudson-Champlain valley under any of the conditions which are shown to have existed during the retreat of the ice sheet.

From a reference to the diagram plate 28, line G–H, it will be seen that the outlet of the Fort Edward stage of Lake Vermont at New York must now be submerged not less than 650 feet if the view taken on page 192 is correct.

DEFORMATION BY POSTGLACIAL FAULTS

From the vicinity of Greenbush northward into Argyle there is a belt of as yet unknown width in which the glaciated surfaces of nearly vertical slates are disrupted by small faults with a downthrow on the west, showing that in postglacial times the land on the western side of the Berkshire hills has come to stand relatively higher than that in the Hudson gorge and on the west of the river. Further detailed work in the field is required to make a quantitative statement concerning the amount of movement on these small faults. I have not been able without this detailed study to determine what role they may have played, if any, in

the tilting of the old water levels in the upper Hudson valley. The following note on the faults at Defreestville shows that these movements may assume some importance in the solution of the problem when their distribution has been accurately determined.

At Defreestville east of Albany a few rods from the road corners on the southeast road from that place there may be seen in the gutter well glaciated rock surfaces broken into small step faults each with a downthrow from a fraction of an inch to as much as 3 inches on the west. In a horizontal distance of 12 feet I measured a westerly downthrow of 1 foot vertical. It is probable that this zone of displacement has narrow limits but the local rate is as great as 440 feet change of level to 1 mile horizontal. The fact that the same small faultings occur on the bank of the river at Greenbush is indicative of a measurable change of local levels in the terrace of this part of the valley. No allowance has been made for these movements in the present report.

Mather[1] reported the existence of similar faults in slate rocks in Copake and Ancram. He mentions a locality near the end of Winchell's mountain and not far from the base of Mt Washington on the road from Copake to Boston Corners. He further cites Professor Merrick as having seen other examples, ½ mile west of Long pond in Clinton, in which the surface was displaced from 2 to 3 inches.

What appears to be a nearly north and south fracture with 3 or 4 feet throw with broken blocks of rock thrown into a narrow fissure occurs on the lake side of Trembleau mountain just south of Port Kent station. The downthrow in this instance is on the east in the direction of the lake valley. On Mt Monnoir near St Johns, Quebec, on the eastern side near the summit, similar evidences of fracturing appear with large inthrown blocks of rock from the sides. One of these cases was within the zone of wave action during the submergence; certainly that at Port Kent was within the zone of marine action. Wave action frequently opens small chasms in jointed and fractured rock but in a regressive movement of the sea it would hardly choke up such openings with large blocks from the sides in tumultuous disorder.

[1] Mather. Geol. N. Y. 1st Dist. 1843. p.156–57.

Chalmers describes small rock fractures of postglacial date in southern Quebec like those above mentioned near Albany, and the same kind of rock movement breaking glaciated surfaces has been reported in New Brunswick by G. F. Matthew.[1] It is evident that the changes of level which have taken place in this region have been accompanied by the local apparently widely distributed faulting of ancient rocks. It is hoped that special investigation of these dislocations in the upper Hudson valley will give data for applying a correction to the local data on which the recognition of the present attitude of the ancient water levels depend.

BEARING OF CHANGE OF LEVEL ON THE DURATION OF THE POSTGLACIAL INTERVAL

The elevation of shell-bearing beds at Montreal on Mt Royal to a hight of 550 feet together with the existence of the ancient marine limit marked by beaches at an altitude of 450 feet near the international boundary on the north slope of Covey hill, affords a basis for the calculation of the time which has elapsed since the marine shore lines were level water lines, provided the rate of tilting and local elevation can be satisfactorily determined. The fact shown in plate 28 and discussed in the preceding pages that an upper water level, apparently of lacustrine nature declines at a rather uniform rate from north to south in the Champlain region makes it evident that the assumption of any given rate of vertical movement e. g. 3 feet a century would be erroneous for all except one point in the elevated district. Far to the north of the international boundary in the Hudson Bay district, Bell has given his reason for thinking that elevation is now taking place at a rate between 4 and 5 feet a century. On the south along the coast at the mouth of the Hudson river, Cook and others have estimated that the coast is now being depressed in relation to sea level at the rate of 2 feet a century; but recent engineering measurements of tidal range show according to Mr George W. Tuttle[2] that at New York city since 1875 the subsidence has been at the rate of 1.45 feet a century. On the contrary from 1853

[1] Matthew, G. F. Post-glacial Faults at St John, New Brunswick. Am. Jour. Sci. ser. 3. 1894. 48:501–3.

[2] See bibliography, No. 148a.

to 1904 there appears to have been on the whole no permanent change of level. At the international boundary the rate must lie somewhere between 2 feet and 5 feet a century. On the Swedish coast elevation appears to be taking place at a rate of from 2 to 3 feet a century. Thus a rate of change of from 2 to 3 feet appears admissible for certain places on the earth's surface. Assuming that there has been constant uplift at Mt Royal, and that the rate has been that locally ascertained in the case of the Baltic coast and placing this at its maximum of 3 feet a century, it would have required 18,666 years to raise the highest shell bed on that mountain from sea level to its present hight above the sea. Again, if we assume that the rate of elevation has been faster at Mt Royal but not greater than 3 feet a century at the international boundary, where the upper limit of the Hochelagan marine invasion now stands at 450 feet, 15.000 years would be required to accomplish the result. This method of attacking the problem it will be seen is not likely to give definite results unless the actual rate of vertical movement at the point where the elevation of the ancient water level is taken be known. In this district the data have not been gathered.

Thanks to Mr Gilbert's studies of the changes of level now taking place in the Great Lake basins the assumption may be made that on one of the radial lines of the apparently dome-shaped uplift which has taken place in this northeastern part of the country the rate of tilting on a south-southwest direction is such as to displace the two ends of a line 100 miles long .42 of a foot in 100 years. The line of water level traceable through Lake Champlain and southward through the Hudson exhibits a displacement showing uplift on the north and depression on the south such as to make the assumption of a southward tilting in this direction at a rate comparable to that made out for the Great Lakes. Making this assumption with the additional postulate that the present rate has held during the past, the following data lead to the conclusion stated below.

At Covey hill on the international boundary the marine limit is 450 feet. Twenty-six miles north a littoral deposit of shells occurs on Mt Royal at the hight of 550 feet. The difference of level today between these two stations is at least 100 feet.

Originally the two localities were at the same sea level. If the tilting took place at the rate of .42 of a foot in 100 miles, in 26 miles it would take place at the rate of .1092 feet in 100 years, and as the Montreal station is 100 feet above that at Covey hill we obtain the ratios (neglecting the third and fourth decimals): as .1 foot is to 100 years, so is 100 feet to the time required to elevate the Mt Royal station 100 feet above the Covey hill station. Solving this simple proportion we obtain 100,000 years as the time required. At this rate the land must have risen at the rate of .55 feet ($6\frac{6}{10}$ inches) a century at Montreal and .45 feet ($5\frac{4}{10}$ inches) a century at the international boundary on the north and south line passing through the Champlain and Hudson valleys.

This estimate of 100,000 years is for the time since the highest marine beach was level. This highest beach marks approximately the time of disappearance of the ice sheet from the St Lawrence valley so as to permit the free incursion of the sea. If the assumption used in this calculation were right it would follow that the Laurentide ice sheet disappeared from the St Lawrence valley as long as 100,000 years ago.

It may be, though, that the rate of tilting in the northsouth direction through the Champlain-Hudson valleys is now and has been at a more rapid rate than that ascertained for the Great Lake district on a south-southwest line. If we assume the rise at Montreal has been at a rate five times as fast as that inferred above or 2.75 feet a century then it has required 20,000 years to effect the change. It does not seem possible that the rate of uplift at Mt Royal could have been on the average more rapid than 2.75 feet in 100 years and there is no reason to assume that it was slower than the rate of tilting now observable in the Great Lakes district. The disappearance of the ice sheet from the low grounds about the northern open mouth of the Lake Champlain valley may be said therefore with some probability to have taken place not less than 20,000 years ago and not longer than 100,000 years ago. That it was somewhere between these limits is more probable than that it was either 20,000 years or else 100,000 years ago.

There is yet another method which though equally interesting is not more trustworthy perhaps. By reference to the diagram, plate 28, it will be noted that on the assumption of essential

rigidity in the movement of the crust from New York to Montreal, when the sea was at the upper marine limit in the Champlain country the site of New York city must have been about 650 feet above sea level. If now the rate of depression which has brought about the change of level at New York postulated by this view be assumed to have been in the long run 2 feet a century, it will have taken 32,500 years to accomplish the change which has occurred since the sea stood at its upper limit in the St Lawrence valley. Such figures mean only that the postglacial epoch or phase for the glaciated portion of the country is to be measured, as Gilbert has stated it, by tens of thousands of years.

COMPARISON OF NORTHERN AND SOUTHERN MOUTHS OF THE HUDSON-CHAMPLAIN DEPRESSION

The most striking differences are apparent in the recent geologic history of the lower Hudson valley and the wide open mouth of the Champlain valley. In the northern area there are abundant beaches of strong development attesting the action of powerful waves with a fetch of wind over wide sheets of water, and certainly the lower of these water levels are marine as abundant marine fossils in sands and clays from an altitude of 350 feet down to the level of Lake Champlain testify. The typical glacial topography over the plains below the marine limit is largely smothered by wave action involving cutting and filling. Where moraines or eskers exist, they are incised by the horizontal lines of wave action. More than all this the existence of a broad estuary is attested by the widespread distribution of clays bordering Lake Champlain, clays on which in the central areas remote from the old shore lines and sand deltas no newer deposits repose.

In the southern area including the vicinity of New York city and the wide valley of the Passaic and Hackensack, a relatively low area analogous to that at the northern end of Lake Champlain, recognizable wave lines have not been found, no undoubted marine beach, bar, or cliff is known to exist above the present sea level. The glacial deposits are, except in marshy and swamp areas at the surface without suffusion by clays which ought to be expected if the region had been submerged for any appreciable length of time. A diligent search conducted for certainly over

half a century by numerous observers whether amateurs or official geologic surveyors has failed to bring to light *postglacial* marine fossils above the level of the sea at the mouth of the Hudson.

The comparison of the extreme ends of the great Hudson-Champlain depression speaks eloquently of marine submergence on the north during a time when the region on the south about the mouth of the Hudson at least was as it now is above the level of the sea.

SUMMARY OF GEOLOGIC HISTORY BEGINNING WITH THE RETREAT OF THE WISCONSIN ICE SHEET

From the foregoing more or less detailed but as yet incomplete account of the successive frontal moraines in the Hudson and Champlain valleys, it follows that the ice front after receding from the moraine at New York Narrows became more and more irregular in outline, more and more reduced to a long loop projecting southward in the Hudson valley and receding northward over the highlands which formed a wall on either side of it. When the ice had so far dwindled away as not to be able to surmount the Archean ridge of the Highlands, it still pushed southward through the Hudson canyon in this elevated district a narrow tongue of ice which has left its marginal deposits of stratified gravel, sand and clay, at Croton Point, North Haverstraw, about Peekskill, and in the vicinity of West Point. During this stage of the waning Wisconsin epoch, the land from the Highlands southward through the lower Hudson valley appears to have been occupied by standing water about the margin of the receding ice. The level of this body of water is now marked by proglacial deltas which rise to the north at the rate of about 2.6 feet a mile;[1] an inclination very close to that found by Kümmel for the shore lines of Lake Passaic in New Jersey.

When the ice disappeared from the Wallkill valley about the northern slopes of the Highlands, it formed a long tongue from Newburg northward covering the greater part of the width of the floor of the Hudson valley. About its margins were accumulated stratified gravels and sands now in the form of terraces, with kettles and ice-block holes, extending on its eastern margin north-

[1]This estimate is obtained by taking the distance, 34.5 miles, from the College Point delta with an elevation of 30 feet, to the terrace used for a state military camp at Peekskill with an elevation of 120 feet.

eastward probably into union with one or more of the morainal stages described by Taylor in the Berkshire hills of northwestern Massachusetts. About the end of the glacier, clays were deposited at Newburg and Fishkill Landing in the northward extended body of water whose shore lines are marked by the earlier formed deltas and terraces of the ice retreat.

From this time on till later in the history of the recession, the retrogression of the ice front is marked by partially revealed gravel and till deposits in the Hudson gorge or over the surface of the rock benches which border it. As the ice front passed the mouths of streams which enter the Hudson, their volume and load of sediment was vastly increased by contributions from the ice on their north bank, thus determining the time of their maximum constructive effect. The result of these changes is seen in the horizontal alternation of deposits of till and gravel with finer sediments at intervals of a few miles in the banks of the gorge from the Highlands northward as far as Rhinebeck north of which region the coating of a later group of clays laid down far beyond the ice front of their time partly conceals the full history of the disappearance of the ice from the immediate vicinity of the gorge.

As soon as the Mohawk valley was opened a large contribution of water charged with fine sediment came into the Hudson valley from that direction and for some time later was distributed far and wide to the south in the form of clays which may be traced as an almost continuous sheet over the rock benches and in the gorge itself as far south at least as Saugerties. The same body of clays extends northward along the Hudson banks at least to the southern border of the Fort Edward district and probably it is the same clay formation though perhaps of a somewhat later stage of deposition which is traceable through the valley of Wood creek into that of Lake Champlain.

The deposition of this clay appears to have been interrupted by an advance of the ice into the Fort Edward district as far south as the northern mouth of the deeper Hudson gorge.

The waters of Lake Albany, in which this clay was deposited, appear to have been shallow and to have covered the rock benches of the gorge as far south as Saugerties, possibly also at Rondout

but south of this latter named point there is no trace of deposits so late as this stage in the glacial retreat now recognizable above the summit line of the walls of the Hudson gorge. It is to be inferred therefore that Lake Albany had its southern limit somewhere in the vicinity of Rhinebeck and Rondout and that south of that point the surface of the rock terraces were then and have ever since been above the level of standing water.

The shore lines of Lake Albany, determined by the hight of marginal deltas, now rise to the north at a somewhat steeper rate then the land on the south of the Highlands, but from Newburg northward for several miles there is great discrepancy in the level of deltas marginal to the gorge, some of the terraced deposits being of a character and elevation to suggest that the water level varied greatly from time to time. On the whole the deltas from Rondout northward to Albany appear to lie in a tilted plane which, if continued southward, passes below that in which the deltas from the Highlands southward lie. This is interpreted to mean that, as time went on, the detritus in the lower Hudson gorge and about its mouth, in and about the terminal moraine, was swept away by powerful currents lowering the level of the waters about the ice margin. This of course could only take place if the land were far enough above sea level to render the water levels in the Hudson valley independent of the control which would be exerted by a submergence in the sea. The facts seem to indicate that the land was so far tilted down on the north and up on the south that Lake Albany, held in by the ice front on the north, was caused to spread over the rock terraces in the upper Hudson valley while an outlet for its waters was found through the gorge on the south of Rhinebeck below that at which the sea stands today.

For a time the waters of Lake Albany extended northward over the Fort Edward district, covering the lower portion of the plateau about Fort Ann; and thence, connecting through the narrow defile of Wood creek, united with a glacial lake which was extending northward in the valley of Lake Champlain pari passu with the retreat of the ice from that valley. The attitude of the land from Lake Champlain southward to the region of Lake Albany was now that of depression on the north so that the floor of Lake

Champlain was below sea level though the sea was as yet excluded by the ice. The region about Fort Edward was above sea level as will be noted from the next feature in the sequence of events.

From some cause which can only be at present postulated from the known conditions of the time and hence probably the effect of the powerful discharge of the drainage through the Hudson gorge, coming not only from the melting ice in the Champlain district but as well as from the intake from Lake Iroquois which was now in existence on the west of the Adirondacks, the waters of Lake Albany were drained off. That this withdrawal was due to a deepening of the Hudson gorge on the south rather than to a change in the attitude of the land is indicated by the fact that the shore lines of the Champlain district show no signs of a disturbance at this time. With the withdrawal of the waters over the Albany district, a divide partly of glacial materials and partly of the bed rock was revealed between the nascent glacial lake over the Fort Edward basin and in Lake Champlain valley and the region on the south, and waters began to spill over this barrier west and south of Schuylerville across those fields which were later the scene of Burgoyne's defeat. Thus Lake Vermont was born, consisting, on the south of the mountainous ridges between two of which Lake George lies, of a shallow lake over the Fort Edward district, and a constantly enlarging body of water on the north, Lake Vermont proper.

The discharge at this spillway is believed soon to have cleared out and shifted into an older channel which forms a now partly abandoned river valley just west of Schuylerville. The stream at this stage entered the Hudson gorge at Coveville with a fall over the Hudson slates at that point. At this time the Hudson gorge proper from Coveville northward to Northumberland must still have been filled with glacial gravels and the clays which may still be seen on the valley sides.

Thus was formed the Coveville stage of Lake Vermont. The water level was now about 100 feet lower than in the previous initial stage, and if the correlation worked out in this report is correct, the lake was at this time about 200 feet above the then sea level. The floor of the Hudson gorge at Coveville was

about 100 feet above sea level as it is today. The Hudson gorge from Coveville southward must have been largely cleared of the clays and other glacial deposits.

Gradually the filling of clays in the old gorge through which the Hudson now passes Schuylerville was removed and the discharge from Lake Vermont fell into this lower channel reducing the level of the waters on the north till they fell to the level of the present divide between the Hudson and Champlain drainage in the Wood creek valley just northeast of Fort Edward, where the lowest point in the hight of land between the St Lawrence and the Hudson valley is only 147 feet above the sea. This stage of Lake Vermont, when all traces of a lake had disappeared about the Fort Edward district, found the Hudson from Fort Edward southward a much more powerful river than it is now.

During the development of Lake Vermont and as soon as the ice had withdrawn from the northern slope of the Adirondacks to the very border of that district, a powerful discharge of water coursed along the ice front from the St Lawrence valley to the eastward and fell into the lake near West Chazy. The course of this torrent is marked by the so called "flat rock" areas from Covey hill southward through Altona. Somewhat later, when discharge at a lower level was permissible, the waters excavated a gorge with a fall at its head on the south side of Covey hill. The Gulf with its lakelets stands as a silent monument of this vanished river.

At a yet later stage, following the stand of the waters in Lake Vermont under the control of the Fort Edward outlet, the ice barrier on the north began to give way; the waters leaked out northward, we are at liberty to suppose, thus lowering the lake level step by step; and then when the ice was no longer a barrier the sea came in at a lower level, the position of which seems to be determined, from a study of the upper limit of beaches on Covey hill, and by the upper limit of shells and the related data in the Champlain valley. As pointed out in the text, the sea appears not to have extended farther south than Whitehall at which time the land on the south was as high if not higher than now.

Subsequent to the invasion by the sea, the land began to rise on the north and to sink on the south, a movement which is, according to the evidence obtained by Gilbert and others in the Great Lake district, and by Cook and others along the coast east and south of New York, still going on. In the valley of Lake Champlain we find the indisputable evidence of uplift as high as marine shells occur. About the mouth of the Hudson we observe evidences of recent sinking and though we can not, from what we see there, determine how long the depression has been going on, it would seem as if the land must have gone as far beneath the sea at that end of our line of ancient water levels as it has risen out of the sea on the far north.

POSTSCRIPT

If the sections of the Hudson river bed near New York city presented by Professor Hobbs[1] in a recent paper include borings to bed rock rather than boulders, it would appear for the first time that the Hudson gorge at the latitude of New York city is not more than perhaps 350 feet deep beneath sea level; but the evidence is as yet by no means conclusive on this point.

[1] Hobbs, W. H. Origin of the Channels surrounding Manhattan Island, New York. Geol. Soc. Am. Bul. 1905. 16:151–82. *See* fig. 22–24 and p.176–79.

APPENDIX

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EXPLANATION OF PLATE 28

This plate is a north-south profile, in which the vertical lines represent the latitude lines, 15 minutes apart, which form the north and south boundaries of the quadrangles or sheets of the state topographic map. The horizontal and inclined lines represent existing and ancient water levels with their angle of tilt in the double scale of the section. One inch vertical equals 533 feet; one inch horizontal equals about 13.3 miles. The legend attached to the sections explains special symbols. The several lines, A-B, etc., indicate the following:

A-B The solid part of the line connects the highest beach found at Port Kent (Plattsburg quadrangle) with the highest beach at Street Road (Ticonderoga sheet) and represents the present tilted attitude of this old water level between the two localities. The dotted extensions of the line north and south meet certain beaches on the north and come near the level of the deltas made in front of the retreating ice sheet in the Highlands and southward; it is a line of comparison. So far as present evidence goes the waters of glacial Lake Albany and Lake Vermont did not rise above the line. The deposits found above the line appear to have been made in local bodies of water marginal to the ice sheet or to have been deposited by glacial streams confined on rock terraces similarly to those at West Point. Further investigation may show that some of the shore line traces along this line on the north and certain deltas in the middle Hudson valley were made at different times in different water bodies.

C-D Lake Vermont, with beaches and deltas, at the time of discharge through the Coveville channel or spillway below Schuylerville. It will be noted that this water level crosses the line A-B at the southern border of the Plattsburg quadrangle near Port Kent. If A-B really coincides with the earlier water level of the Champlain valley, it follows that the land was tilted down toward

the north after the waters abandoned the A-B level and before C-D was formed, causing the waters on the north of Port Kent to submerge the old level.

E-F Lake Vermont at the next lower stage after the opening of the old gorge through which the Hudson now flows at Schuylerville, and when the outlet of the lake was in the Wood creek channel near Dunham basin above Fort Edward, the present divide between the Hudson and Champlain drainage.

G-H Represents the extension of the present inclination of the bed of the Hudson gorge from the divide at E southward to the head of tide where the rock floor disappears. If the above water levels are correctly measured, it is necessary to suppose that the rock floor of the Hudson is at least as deep at any particular point in the Hudson valley as the line G-H indicates for that point, and since the bed of the rock gorge must have deepened toward the mouth on the south the real depth of the gorge is presumably deeper than is indicated by the line G-H.

H-E-I Indicates the profile of the bed of the rock channel from near Mechanicville to Whitehall at the head of Lake Champlain.

J-K The approximate level of Lake Champlain, 98 feet above sea level.

L-M The inclination of the upper marine limit. Note that since E-F was level the land has risen more at the international boundary than at Whitehall for E-F and L-M are not parallel. M is at Mt Royal back of Montreal, Canada.

N-O A line passing through the highest shell localities from Montreal (550 feet) along the western side of Lake Champlain to near the head of the lake. A straight line passing through the two highest shell localities would meet the surface of Lake Champlain near Whitehall.

P-Q Present sea level.

R-S The level of Lake George.

The numerals indicate the following localities, a description of which will usually be found at the page indicated:

1 College Point delta, Harlem sheet [p. 90]
2 Tappan moraine and outwash plain [p. 93, pl. 2]; Tarrytown sheet
3 Tarrytown delta, Gory brook; Tarrytown sheet [p. 96]
4 Ice front at Croton point; Tarrytown sheet [p. 98]
5 North Haverstraw frontal terrace; Tarrytown sheet [p. 100]
6 West Point and Cold Spring terraces; West Point sheet [p. 111]
7 Roseton terrace; west bank of Hudson; Poughkeepsie sheet [p. 119]
8 New Hamburg lateral moraine terrace, mouth of Wappinger creek; Poughkeepsie sheet [p. 119, pl. 5]
9 Marlboro lateral moraine terrace; west bank of Hudson [pl. 5]
10 Lateral moraine terrace south of Hyde Park; Rhinebeck sheet [pl. 6]
11 Lateral moraine kettle terraces from Cokerville northeastward through Livingston; east side of Hudson; Catskill sheet [p. 121, pl. 7]
12 Lateral moraine terrace kettles 2 miles northwest of West Coxsackie; west side of Hudson [not further described]
13 Schodack terrace; Troy sheet [p. 122, pl. 8]
14*a* Kenwood terrace, a faint river terrace west bank of Hudson near Kenwood; Albany sheet [p. 199]
14*b* Kame terrace southeast of West Sandlake [p. 126]; Troy sheet
15 Cooper pond kame terraces; Troy sheet [p. 227]
16 Supposed ice front north side of Mohawk delta near Schenectady; Schenectady sheet [p. 131]
17 Hoosic delta; Cohoes sheet [p. 134, pl. 10]
18 Delta of the Batten kill, south of the stream. The delta symbol on right and lower down stands for the delta plain north of the river [p. 137, pl. 11]
19 Old outlet of Lake Vermont; symbol placed at Grangerville; Schuylerville sheet [p. 196, pl. 11]
20 Glacial terrace at Moreau pond [pl. 12]; Schuylerville sheet

21 400 foot terrace delta of Adirondack-Hudson; east base of Palmertown mountain; 350-60 foot terrace farther east; Glens Falls sheet [p. 145, pl. 13]

22 Outlet of Lake Vermont, Fort Edward stage; in channel near Dunham basin; Glens Falls sheet [p. 198, pl. 13]

23 Terrace plain southwest of Glen lake about 1 mile southwest of Rush pond; Glens Falls sheet [pl. 13]

24 349 foot outlet (?) south of Lake George east side of French mountain; Glens Falls sheet

25 Outwash plain from ice at southern end of Lake George, north of Bloody pond; Glens Falls sheet

26 Delta of the Mettawee river; West Granville; Fort Ann sheet [p. 149]

27 Delta of the Poultney river, Fairhaven Vt.; Whitehall sheet [p. 150]

28 Probable beach lines east base of Cooks mountain; Ticonderoga sheet

29 Boulder pavement north base of Cooks mountain, south of Trout brook; Ticonderoga sheet

30 Shore line of flat east of old Fort Ticonderoga; Ticonderoga sheet

31 Upper beach line on glacial terrace, Sawyers hill, north of Street Road; Ticonderoga sheet [p. 155, pl. 15]

32 Stony beach line 1.5 miles northwest of Crown Point Center; Ticonderoga sheet [pl. 15]

33 Surface of terrace 2 miles northwest from Crown Point; Ticonderoga sheet [pl. 15]

34 Wave-cut lines on shoal 1.5 miles northwest from Burdicks crossing; Ticonderoga sheet [pl. 15]

35 Gravel terrace on Grove brook, southwest of Port Henry; Port Henry sheet [pl. 16]

36 Fragment of delta south side of Mill brook, back of Port Henry; Port Henry sheet [pl. 16]

37 Probable shore lines back of Port Henry [pl. 16]

38 Faint beach at base of rock cliff north of Port Henry and east side of abandoned mines and village [pl. 16]; Port Henry sheet

39 Fossil shells on Crown Point peninsula [p. 213]

40 Wave-cut (?) terrace levels on delta of Mullen brook [pl. 16]; Port Henry sheet

41 Fossil shells near Willsboro; Willsboro sheet [p. 213]

42 Wave-heaped ridge back of Port Douglas; Willsboro sheet

43 Spitlike deposit of coarse debris north side of Trembleau mountain, back of Port Kent; Plattsburg sheet [pl. 21]

44 Dissected delta of Ausable at Keeseville, and shore lines; Plattsburg sheet [pl. 21]

45 Sea cliff cut in till near old tollgate, back of Port Kent; shore lines in till above cliff; also approximate surface of a delta plain of the Ausable [p. 204, pl. 21]

46 Fossil shells near Port Kent railroad station [p. 212, pl. 21]

47 Fossil shells; Freydensburg's mills on the Saranac; Plattsburg sheet [p. 211]

48 Faint beach south by west from Beekmantown, southern edge of Mooers sheet [pl. 29]

49 Beach ridge or broad bar in Beekmantown, south of Silver Creek; Mooers sheet [pl. 29]

50 Cobblestone hill, wave-washed moraine; about 3 miles northwest from West Chazy; Mooers sheet [p. 172, pl. 29]

51 Altona delta; at Altona; Mooers quadrangle [p. 172, pl. 29]

52 Dissected delta on the north branch of the Big Chazy river south of Deer pond in Mooers; Mooers sheet [pl. 29]

53 Cobblestone beach ridges with hooks; at head of Kellas brook; Armstrong's Bush, northwest corner of Mooers sheet [p. 172, pl. 29]

54 Spillway at the Gulf, head of upper lakelet, south of Covey hill, partly in Canada [p. 161, pl. 25]

55 Faint beach flat on Kellas brook, Armstrong's Bush, northwest corner Mooers sheet [p. 172, pl. 29]

56 Highest of the series of beaches between 538 and 360 feet along the international boundary west of west branch of English river [p. 173, pl. 29]

57 Delta of the English river [pl. 29]

58 Fossil shells; Big Chazy river, 1 mile above Thorn; Mooers quadrangle [p. 210]

59 Delta of the Big Chazy river at Mooers; Mooers sheet [pl. 29]

60 Upper marine limit on the north slope of Covey hill, Canada, between Vicars and Franklin [p. 173, pl. 25]

61 Fossil shells south of Hemmingford, Quebec [p. 210]

62 Fossil shells at Côte des Neiges, on Mt Royal, Montreal, Quebec [p. 209]

INDEX

The superior figures tell the exact place on the page in ninths; e. g. 179^{3} means page 179, beginning in the third ninth of the page, i. e. about one third of the way down.

Adams, C. B., cited, 221^{1}.
Adirondack Hudson, three deltas, 147^{1}-49^{5}.
Albany, Lake, 175^{1}-89^{9}, 241^{9}-43^{4}; correlation with the western great glacial lakes, 178^{8}-79^{3}.
Albany clays, 175^{8}, 217^{9}; conditions under which they were deposited, 179^{3}-89^{9}.
Altona, delta, 172^{6}.
Ancram, faults, 235^{5}.
Argyle, deposits in, 144^{4}.
Arlington clay deposit near Poughkeepsie, 126^{6}.

Balanus *sp.*, 211^{4}, 212^{4}, 213^{2}.
miser, 212^{9}.
Baldwin, S. P., cited, 152^{7}, 168^{2}, 171^{5}, 201^{9}, 211^{8}, 214^{1}, 214^{5}, 214^{7}, 220^{8}, 222^{1}, 246^{4}.
Ballston channel, 75^{9}-76^{5}.
Barnes, cited, 246^{4}.
Bassett, C. C., cited, 122^{3}.
Bather, F. A., cited, 184^{9}.
Batten kill, delta of, 137^{3}-38^{3}.
Beaches of the Champlain valley, 168^{1}-74.
Bell, cited, 236^{7}.
Bibliography, 246-53.
Brainerd, A. F., cited, 246^{5}.
Brigham, A. P., cited, 116^{9}, 246^{5}.
Britton, N. L., cited, 228^{9}, 246^{5}.
Brogger, W. C., cited, 246^{7}.
Bryson, John, cited, 246^{7}.
Buchanan, cited, 72^{6}.
Bulla, 212^{7}.

Cadyville, delta, 160^{8}, 171^{5}.
Cape May formation, 233^{4}.
Catskill creek, character of valley, 231^{2}.
Cedar pond brook and its deposits, 100^{5}-2^{5}; character of valley, 230^{8}.
Chalmers, cited, 236^{1}, 246^{8}.
Chamberlin, T. C., cited, 247^{1}.
Champlain, glacial Lake, 190^{1}-200^{9}.
Champlain, Lake, Indian name, 220^{9}.
Champlain clays, 218^{5}.
Champlain deposits, distribution of fossils in, 208^{1}-16^{7}.
Champlain group, 218^{6}.
Champlain valley, physiography of, 77^{5}-78^{3}; retreat of ice sheet in, 152^{1}-64; northward extension of clays into, 167^{6}; deltas, 168^{1}-74; shore lines, 168^{1}-74.
Channels of the upper Hudson valley, 75^{2}-77^{4}.
Cheesequake creek, terrace at mouth of, 87^{9}-88^{9}.
Chironomus motilator, 186^{8}.
Clarke, J. M., cited, 218^{7}.
Clay deposits, exceptional reasons for predominance of, 185^{9}-86^{5}.
Claypole, E. W., cited, 247^{3}.
Clays, northward extension into Champlain valley, 167^{6}; organisms of in the Hudson river valley, 186^{5}-87^{7}; contorted, 188^{5}-89^{9}; deposition, 241^{6}; in Champlain valley, marine origin, 220^{7}.
Cliff in till near Port Kent, 204^{5}-5^{8}.
Cold Spring, terraces about, 111^{4}-14^{9}.
Coleman, A. P., acknowledgments to, 67^{9}; cited, 163^{4}, 208^{3}, 208^{9}, 247^{4}.
College Point delta, 90^{9}-91^{4}.
Contorted clays, 188^{5}-89^{9}.

Cook, G. H., cited, 236^8, 245^2, 247^5.
Coolidge, P. T., cited, 213^2.
Copake, faults, 235^5.
Corinth, delta at, 147^2.
Cornelius, E., cited, 247^5.
Cornwall terrace, 115^7-16^4.
Corson, J. P., cited, 247^5.
Coveville outlet, 196^2-97^7.
Coveville stage of Lake Vermont, 243^9-44^1.
Covey hill, evidence from the northern face of, 162^8-64^1; shore lines about, 173^5-74^4.
Croll, J., cited, 247^6.
Crosby, W. O., cited, 247^6.
Croton point, 102^5-5^8; deposits south of, 96^5-98^3.
Croton point stage, 98^3.
Croton river, character of valley, 230^1.
Crown Point Peninsula, fossils on, 213^6.
Crugers, clays at, 105^8-6^7.
Cushing, H. P., cited, 168^8, 210^9, 247^8.
Cut cliff in till near Port Kent, 204^5-5^8.
Cylichna alba (?), 209^1, 213^2.

Dana, J. D., cited, 72^9, 219^4, 247^7.
Dannemora mountain, southern slope of, 160^6.
Danskammer terrace, 119^3.
Darwin, Charles, cited, 184^9.
Davidson, G., cited, 72^9.
Davis, W. M., cited, 75^2, 247^9.
Dawson, George M., cited, 167^4, 187^8.
Dawson, Sir J. W., cited, 210^2, 215^7, 215^8, 218^8.
Deformation by postglacial faults, 234^7-36^3.
Defreestville, faults, 235^1.
De Geer, cited, 221^7.
De Kay, J. E., cited, 247^9.
Delebecque, cited, 72^9.
Deltas, three, of Adirondack Hudson, 147^1-49^5; of the Champlain valley, 168^1-74.
Desor, E., cited, 218^1, 248^1.
Dewey, C., cited, 248^2.
Dresden gravels, 153^6-54^9.
Dryer, C. R., cited, 248^3.
Duparc, cited, 72^9.
Durkeetown terrace, 138^3.
Dwight, W. B., cited, 188^9, 248^3.

East Bouquet mountain, parallel roads on, 168^6.
Eaton, A., cited, 248^4.
Eights, J., cited, 186^9, 248^5.
Elevation of land in the southern Hudson valley, evidence of higher, 229^4-31^9.
Elevation theory, possible objections to, 232^1-34^7.
Emerson, B. K., cited, 181^1, 186^8, 186^9.
Emmons, Ebenezer, cited, 76^5, 161^8, 175^8, 188^5, 212^5, 215^8, 218^7, 221^3, 248^5.
Englewood sand plain, 92^6-93^2.
Esopus creek, character of valley, 231^1.
Explanation of plates, 254-59.

Fairchild, H. L., cited, 163^6, 248^6.
Fairhaven Vt., delta of Poultney river at, 150^6-51^3.
Far Rockaway gravels, 233^4.
Far Rockaway ridge, 89^6-90^3.
Faults, postglacial, deformation by, 234^7-36^3.
Finch, J., cited, 248^7.
Fishkill creek, character of valley, 230^7.
Fitch, Asa, cited, 166^3, 176^6, 187^2, 229^1.
Flat Rock spillways, 161^2-62^7.
Forel, F. A., cited, 72^4.
Fort Edward district, 138^9-51^3; below the glacial terraces, 143^2-44^4.
Fort Edward outlet, 198^4.
Fossils, in Champlain deposits, distribution of, 208^1-16^7; depth of submergence indicated by, 215^4-16^7.
Freydenburg's Mills, fossils at, 211^8-12^6.
Frontal moraine, 98^9-100^5.
Fuller, M. L., cited, 90^1, 233^2, 248^7.

Gansevoort, delta at, 147^2.
Geologic history, summary of, 240^8-45.
George, Lake, valley of, 165^1-67^9.
Gilbert, G. K., acknowledgments to, 67^4; cited, 112^1, 153^2, 161^8, 162^8, 163^1, 163^4, 168^3, 173^6, 181^3, 229^1, 237^6, 239^3, 245^1, 248^8.
Glacial clays, succession of, 185^6.
Glacial deposits, of middle Hudson valley, 115^1-33^9; of upper Hudson valley, 134^1-51^9.
Glacial lakes, 175^1-200^9.
Glacial movement, through the Hudson and Champlain valleys, 78^4-79^8.
Glacial potholes, 228^7.
Glacier, regional, theoretic mode of retreat from a valley, 79^8-86^9; melting, successive stages in the cross-section of, 84^5-86^9.
Glen Lake kettle terrace, 140^8-41^7.
Glens Falls delta, 144^7-47^1, 148^8.
Gordon, R., cited, 249^1.
Gorge of the Hudson, 71^1-73^9, 198^8-99^2, 245^5.
Grabau, A. W., cited, 249^1.
Grant, W. H., cited, 249^2.
Gratacap, L. P., cited, 249^2.
Gray, Alonzo, cited, 221^1.
Green, J., cited, 249^3.
Gulf, the, 161^3.

Hagar, A. D., cited, 218^5, 249^9.
Hall, C. E., cited, 249^4.
Hall, James, cited, 186^7, 249^4.
Harkness, shore lines at, 171^1.
Harrisina hollow, 165^6.
Hartford, deposits in, 144^4.
Haverstraw glacial deposits, 98^7.
Hayden, H. H., cited, 231^9, 249^5.
Hemmingford, Quebec, fossils at, 210^4.
Hitchcock, Charles H., cited, 218^6, 249^5.
Hitchcock, Edward, cited, 218^5, 249^8.
Hobbs, W. H., cited, 245^4
Hochelagan formation, 220^5.
Hollick, A., cited, 249^9.
Hoosic delta, 134^4; dissection of, 200^2.
Hubbard, O. P., cited, 228^9, 249^9.
Hudson river, west bank between Schuylerville and Stillwater township, 135^1;
gorge of: 71^1-73^6; at New York city, depth below sea level, 72^8, 245^5; reexcavation of, 198^8-99^2.
Hudson rock terraces, 73^7-75^2.
Hudson valley, physiography of, 68^1-77^4; longitudinal divisions of, 68^9-73^6.
Hudson-Champlain depression, comparison of northern and southern mouths of, 239^4-40^2.
Hunt, T. S., cited, 250^1.
Hutchinson creek, 92^1.
Hyalonema, 186^7.

Ice sheet in Champlain valley, retreat of, 152^1-64.

Jones, C. C., cited, 250^1.
Jones Point, terrace at, 107^2-9^2.
Julien, A. A., cited, 250^2.

Kame terraces, lateral, 121^5-22^8.
Kellogg, D. S., cited, 211^8.
Kemp, J. F., cited, 165^6, 250^3.
Kendrick's hill, 135^6.
Kenwood terrace, 199^6-200^2.
Kettle holes marginal to the Hudson and Champlain valleys, distribution of, 226^4-28^7.
Kettle terraces of Sandlake and Poestenkill, 126^3.
Keyes, C. R., cited, 250^3.
Kimball, J. P., cited, 250^3.
Kümmel, cited, 240^7.

Lake Albany, *see* Albany, Lake.
Lake Champlain, *see* Champlain, Lake.
Lake George, *see* George, Lake.
Lake Vermont, *see* Vermont, Lake.
Landslips, 187^7-88^4.
Laurentian, term, 218^3.
Lawrentian clays and sands, 218^1.

Leda arctica, 211^{3}, 213^{4}.
portlandica, 213^{4}.
Leda clay, 218^{8}.
Lesley, J. P., cited, 250^{4}.
Level, bearing of change of, on the duration of the postglacial interval, 236^{4}-39^{3}.
Lewis, E., cited, 250^{4}.
Lewis, H. C., cited, 250^{5}.
Lindenkohl, A., cited, 72^{9}, 250^{5}.
Logan, cited, 218^{3}.
Low level terraces, 111^{2}.
Lyell, Sir Charles, cited, 209^{9}, 212^{7}, 250^{6}.

Macfarlane, T., cited, 250^{6}.
McGee, W. J., cited, 250^{7}.
Macoma calcarea, 208^{8}.
groenlandica, 208^{8}, 208^{9}, 209^{3}, 209^{6}, 209^{9}, 211^{3}, 212^{4}, 213^{1}, 213^{3}, 213^{4}, 213^{5}, 213^{6}, 216^{5}.
Manhasset formation, 233^{8}; exposure, 90^{2}.
Marginal lakes, 152^{5}.
Marine conditions, southern extension of, history of opinion concerning, 220^{6}-22.
Marine deposits, of the Champlain valley, 206^{3}-7^{9}; nomenclature of, 216^{8}-20^{6}.
Marine invasion, 201^{1}-22.
Marine limit, upper, 201^{6}-6^{3}.
Marine shells on the Vermont shore, 213^{7}-15^{3}.
Marsh, G. P., cited, 184^{9}.
Martin, D. S., cited, 250^{8}.
Mather, W. W., cited, 133^{8}, 235^{5}, 250^{9}.
Matthew, G. F., cited, 236^{2}.
Meadowdale stage, 128^{7}-29^{5}.
Melosira granulata, 186^{7}.
Merrick, cited, 235^{5}.
Merrill, F. J. H., acknowledgments to, 67^{8}; cited, 223^{6}, 250^{9}-51^{3}.
Mettawee river, delta of, 149^{6}-50^{6}.
Meunier, S., cited, 184^{9}.
Mitchella repens, 186^{9}.
Mohawk delta, 130^{7}-31^{8}.
Montreal, fossils at, 209^{8}-10^{8}.
Moodna kill, terraces, 199^{2}.
Mo[illegible], fossils near, 210^{8}-11^{7}.
Mo[illegible]ley, quadrangle, shore lines of, 172-73.
Morton, S. G., cited, 251^{8}.
Moses kill, washed rocks near the mouth of, 197^{8}-98^{4}.
Mya arenaria, 212^{7}.
truncata, 212^{7}.
Mytilus edulis, 212^{4}, 212^{7}, 212^{9}, 213^{2}, 213^{5}, 216^{5}.

Navicula gruendeleri, 186^{7}.
permagna, 186^{7}.
New Hamburg glacial deposits, 119^{5}-21^{3}.
Newburg and related stages, summary of, 131^{9}-33^{9}.
Newburg stage, north and east of New Hamburg, ice edge, 121^{3}.
Newburg terrace, 116^{4}-18^{9}.
Nitzschia granulata, 186^{7}.
Nomenclature of the marine deposits, 216^{8}-20^{6}.
North Albany gravels, 129^{5}-30^{7}.
North Argyle, morainal terrace at, 142^{5}-43^{2}.
Norwood, fossils at, 209^{3}.
Nucula portlandica, 212^{7}.
Nyack terraces, preglacial, 95^{6}-96^{2}.

Ogdensburg, fossils at, 208^{7}-9^{8}.
Ogilvie, I. H., cited, 251^{3}.
Organisms of the clays in the Hudson river valley, 186^{5}-87^{7}.
Osborn, H. F., cited, 228^{9}, 251^{4}.
Outwash plains, 90^{6}.

Palmertown mountain, terrace, 140^{2}; delta at base of, 147^{2}.
Patten's Mills terrace, 141^{8}-42^{5}.
Pecten islandicus, 212^{7}.
Peekskill, terrace in, 109^{2}.
Peekskill bay, terraces about, 106^{7}-13^{7}.
Peekskill cove, character of valley, 230^{5}.
Peekskill creek terraces, 109^{9}-11^{1}.
Peet, C. E., cited, 213^{9}, 251^{4}.
Pelham, deposits near, 92^{1}.
Perry, J. B., cited, 251^{4}.

Perth Amboy, glacial delta near, 91^5.
Physiography, of the Champlain valley, 77^5-78^8; of the Hudson valley, 68^1-77^4.
Plates, explanation of, 254-59.
Poestenkill, kettle terrace of, 126^2.
Popolopen creek, character of valley, 230^6.
Port Douglas beach ridge, 168^8-69^1.
Port Ewen deposits, 126^9-27^4.
Port Henry, possible local glacier at, 156^1-60^5.
Port Kent, shore lines and deltas about, 169^1; cut cliff in till near, 204^5-5^8; fossils at, 212^5-13^4.
Port Washington delta, 90^9-91^4.
Portlandia *sp.*, 211^3.
Postglacial epoch, duration, 239^3.
Postglacial interval, bearing of change of level on the duration of, 236^4-39^3.
Potholes near the Hudson gorge, evidence from, 228^7-29^3.
Poultney river, delta of, 150^6-51^8.
Price, E. K., cited, 251^5.
Prodelta clays, 181^6-85^6.

Quaker Springs outlet, 193^9-96^2.

Rand hill, southern slope of, 160^6; moraines north, east and west of, 160^8-61^2.
Reclus, E., cited, 184^9.
Redfield, W. C., cited, 251^5.
Reed, S., cited, 251^7.
Retreat of ice sheet in Champlain valley, 152^1-64.
Reusch, Hans, cited, 187^9.
Richardson, cited, 214^5.
Ries, H., cited, 110^9, 186^7, 251^7.
Rock channels of the upper Hudson valley, 75^2-77^4.
Rock terraces, Hudson, 73^7-75^2.
Roeliff Jansen kill, 231^2.
Rogers, H. D., cited, 208^4, 251^8.
Rondout creek, character of valley, 230^9.
Rondout terrace deposits, 127^5-28^7.
Roseton terrace, 119^1.
Round lake channel, 76^6-77^1.
Russell, I. C., cited, 104^9, 188^8.

Safely, R., cited, 251^9.
Salisbury, R. D., cited, 79^4, 89^9, 92^6, 232^8, 251^9.
Sandlake, kettle terrace of, 126^2.
Saranac, deltas of, 171^4.
Saratoga lake region, 135^8-37^2.
Saxicava rugosa, 208^9, 209^9, 210^4, 211^3, 212^4, 212^9, 213^1, 213^8, 213^4, 215^3, 216^5.
Saxicava sand, 218^3.
Schaeffer, F. C., cited, 252^1.
Schodack glacial terrace, 122^9-24^5.
Schuchert, Charles, cited, 218^7.
Sea cliff in till near Port Kent, 204^5-5^8.
Shaler, N. S., cited, 252^1.
Shore lines of the Champlain valley, 168^1-74.
Smock, J. C., cited, 252^2.
South Bethlehem terrace, 124^6-26^1.
Southern Hudson valley, evidence of higher elevation of land in, 229^4-31^9.
Spencer, J. W., cited, 252^2.
Spillways, Flat Rock, 161^2-62^7.
Staten Island, unglaciated area of, 89^1.
Steele, J. H., cited, 252^2.
Stevens, R. P., cited, 252^3.
Stockport creek, character of valley, 231^3.
Street Road terrace, 154^9-56^1.
Suess, Ed., cited, 72^6, 252^3.

Tappan moraine, 93^9-95^6.
Tarrytown delta, 96^2.
Taylor, F. B., cited, 152^6, 164^6, 168^2, 241^1, 252^4.
Tellina *sp.*, 212^6.
groenlandica, 209^9, 212^9.
Terminal moraine, 90^6.
Terraces, at mouth of Cheesequake creek, 87^9-88^9; of Fort Edward district, 139^3; of Hoosic delta, 200^4; Hudson rock, 73^7-75^2; of middle Hudson valley, 115^7-29^5; Kenwood, 199^6-200^2; of the

Moodna kill, 199^{2}; about Peekskill bay, 106^{7}-13^{7}. *See also* Water levels.
Thomas, D., cited, 252^{4}.
Thompson, W. A., cited, 252^{4}.
Tomkins Cove, terrace at, 106^{9}-7^{1}.
Tomlinson, C. H., cited, 252^{5}.
Trembleau mountain, 169^{9}.
Tritonium anglicum, 212^{6}.
fornicatum, 212^{6}.
Turritella, 212^{7}.
Tuttle, George W., cited, 236^{9}, 252^{6}.

Upham, W., cited, 153^{4}, 168^{2}, 190^{6}, 220^{8}, 221^{4}, 252^{6}-53^{2}.

Vaccinum oxycoccus, 187^{1}.
Van Cortlandt park plain, 93^{2}.
Veatch, A. C., cited, 73^{2}, 90^{1}, 233^{2}, 248^{7}.
Verbeck, Chevalier, cited, 184^{8}.
Vermont, Lake, 190^{1}-200^{9}, 243^{6}; outlets of, 193^{4}-200^{9}; Coveville stage, 243^{9}-44^{1}.
Vermont shore, marine shells on, 213^{7}-15^{8}.

Wappinger creek, character of valley, 230^{8}.
Warring, C. B., cited, 253^{2}.
Water levels, extraglacial evidence, 87^{6}-90^{8}; interglacial evidence, 90^{8}-114^{9}; of Champlain and Hudson valleys, comparison of, 223^{3}-26^{4}.
Watson, T. L., cited, 253^{3}.
Watson, W. C., cited, 253^{3}.
West Point, terraces about, 111^{4}-14^{9}.
Willcox, J., 253^{4}.
Willsboro, fossils at, 213^{5}.
Winchell, A. N., cited, 253^{4}.
Wisconsin ice sheet, retreat of, 87^{1}-114^{9}, 240^{8}-45.
Wood creek, channel, 77^{1}; valley of, 165^{1}-67^{9}.
Woodworth, J. B., cited, 233^{9}, 253^{5}.
Wright, G. F., cited, 168^{2}.

Yoldia (Portlandia) *sp.*, 211^{8}.
Youmans, E. I. ?, cited, 253^{5}.

Zeppelin, Eberhard Graf, cited, 72^{9}.

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Bulletin 95

GEOLOGY 9

GEOLOGY

OF THE

NORTHERN ADIRONDACK REGION

BY

H. P. CUSHING

	PAGE
Introduction	271
Summary of geologic history	272
Precambric history	273
Early Paleozoic history	279
Later Paleozoic changes of level	285
Paleozoic disturbances	286
Paleozoic igneous activity	287
Paleozoic erosion	288
Mesozoic history	289
Cenozoic history	290
Glacial history	292
Postglacial history	293
The rocks	294
Precambric rocks	294
Paleozoic rocks	354
Rock structures	399
Foliation	399
Folds	402
Paleozoic rocks (*continued*)	
Faults	403
Joints	412
Topography	416
Introduction	416
Prepotsdam topography	418
Paleozoic topography	419
Appalachian uplift	421
Mesozoic base-leveling	423
Peneplains	425
Main axis of elevation	427
Lake belt	429
Faults as topographic features	430
North plain	433
Northern hills and valleys	434
Streams	437
Lakes	445
Index	449

New York State Education Department

New York State Museum

John M. Clarke Director

Bulletin 95

GEOLOGY 9

GEOLOGY
OF THE
NORTHERN ADIRONDACK REGION

INTRODUCTION

The writer's work in the Adirondack region has been mainly confined to Clinton and Franklin counties, and what is set forth in the present report is mainly the result and summation of that work. In addition some detailed investigation has been done in western St Lawrence county and in the region about, and northward from, Little Falls in Herkimer county. Brief reconnaissance trips have also been made in Essex and Hamilton counties. Professors Kemp and Smyth have worked during the same period in other parts of the region. They were the pioneers and generously made room for me. We have all worked most pleasantly and harmoniously together and in consultation, in correspondence, and in combined work in the field have freely shared ideas with one another. How large a part of my present views concerning the geology of the region is due to this free intercommunication, I am wholly unable to say. I only know that the indebtedness is great, is fully appreciated and gratefully acknowledged.

The Adirondack region is in many respects a difficult one in which to study geology. The universal forest covering, the difficulty of getting about, greatly increased in burned districts and in those littered with the lumberman's refuse, the frequency of rains and the scarcity or absence of settlements in most of the district are hindrances to work in many respects, specially since

the complicated character of the geology necessitates a careful survey of the whole ground. The work has been greatly hampered also by the very imperfect character of the maps available, the new maps as yet barely reaching the region under consideration. The healthful and invigorating climate and the abundance of pure water are great compensations in their way.

The problems presented for solution are of the most difficult sort. The interpretation of the present topography, the working out of the complex history of the region during Glacial times and the deciphering of the complicated structure and history of the older rocks of the region are all matters requiring long and patient labor and the undivided attention of the worker. The writer's attention has been centered mainly on the latter problems, hence such work as has been done on the others has been incidental, and the fragmentary character of the results obtained is fully appreciated. Prof. J. B. Woodworth is now occupied with these matters, and, when his work is extended over the immediate region, great and important additions to our knowledge are sure to follow.

The summary of the geologic history of the region with which the report opens is for the convenience of the reader. The detailed evidence on which that summary is based will follow later and must be taken for granted till presented.

SUMMARY OF GEOLOGIC HISTORY

The rocks now exposed at the surface in the Adirondack region proper, are among the most ancient rocks known anywhere on the earth's surface, so that their record carries us far back, back to the remoter times of the geologic history of the earth. This early record is exceedingly difficult to decipher because of the great age of the rocks, because of the fact that they have been vastly modified in character by repeated action of great compressive forces, and because the rocks now at the surface were, at an early stage in the history of the region, deeply buried under several thousand feet of other rocks which have since been worn away. It was while thus deeply buried that the major part of

this change from their original character was effected. But the character of the change brought about by compression varies with the depth of the rocks beneath the surface because of hightened temperature and pressure, and rocks may become so greatly modified as to lose all trace of their original character.

Precambric history

Old sediments. The oldest rocks which have with certainty been recognized in the Adirondack region consist of certain well banded gneisses and schists, with bands of varying thickness of coarsely crystalline limestone. They are believed to be old water-deposited rocks, ancient sheets of sand, mud and calcareous mud, deposited on the floor of some large body of shallow water, in all probability the sea. They are now so greatly changed from their original condition that the structures and textures characteristic of rocks so formed have been almost wholly destroyed, being replaced by others which are not characteristic, since they may be produced in igneous rocks as well. The inference as to their original condition is based partly on their composition, and partly on the fact that they show frequent and rather abrupt alternations in character, as if they had originally consisted of beds and layers of varying composition, as water-deposited rocks do. There is apparently a great thickness of these beds, but their base has never been made out with certainty nor is their summit known, so that our ideas concerning their thickness are of the vaguest. They must have been laid down on a surface of older rocks; but we are at present wholly in the dark as to whether or not these older rocks are anywhere exposed in the district at the present time. Rocks which may not improbably represent them, are present and will be shortly described, but no exposures which will enable a decision in the matter have been discovered, nor are they likely to be in the immediate district, though perhaps such may be found to the west or south.

Though unknown, the thickness of these deposits is great, with repeated changes in character, so that it is beyond question that the submergence endured for a long, a very long time, during

which many changes in conditions occurred, as shown by the changes in character of the rocks.

Closely involved with these rocks are others which would seem to be of igneous origin, so far as may be judged from their composition. The great changes which they have undergone have destroyed their original characters utterly, and they have been stretched out into bands parallel with the associated sediments, causing them to appear as an integral part of the series. It seems quite certain that they are, in part at least, igneous, and that they must be somewhat younger than the sediments, except in so far as they may possibly represent subaqueous surface flows, yet they can not be greatly younger, since they have undergone much the same changes, both in kind and in degree, that the sediments have experienced. Wherever the sediments occur, these igneous rocks are sure to be found associated with them, thus indicating widespread and profound igneous activity at the time.

Rocks of doubtful age. In many parts of the region, and running in a broad belt across Clinton and Franklin counties, is found a group of old rocks, profoundly changed from their original condition, which seem to be wholly of igneous origin, so far as can be judged from their composition; at least no rocks similar to those of the preceding group and which are judged to be sediments occur with them. They have been equally, if not more changed from their original condition than have the rocks of the preceding group, and all traces of their original structures have been destroyed. It is by no means impossible that they are older and represent the rocks of the floor on which that group was laid down; indeed, if any remnants of that floor remain, we have them here. But, since similar rocks, in general not to be distinguished from them, occur associated with the sediments, where they are clearly as young, or younger, these may represent great masses of such rocks, massed in such amount as to have wholly displaced the sediments. We are not able to decide these questions as yet. If but one rock group is represented, it is no older than the sediments. If more than one be present, one may be older. But, if so, we as yet lack the means of discriminating between them.

The rocks at present found in the district embrace only a fragmentary remnant of those formed at this early time, a great thickness of other rocks having been laid down above them and later worn away. Twenty thousand to twenty-five thousand feet is not an exaggerated estimate of this thickness. It is not meant to imply that a uniform amount has been removed from the whole district, in fact there is every reason to believe that the opposite is true, that the region has been for much of its history a rugged one, and that much greater removal has taken place from the hights than from the depressions. While this accumulation of the rocks which have since disappeared was in progress, the region was in all probability below sea level and keeping pace with the deposit by a slow subsidence. Not improbably a great part of the accumulated thickness consisted of igneous rocks.

Great igneous intrusions. After the present surface rocks had become deeply buried, they were invaded from beneath by a series of great igneous intrusions, broken up into patches and no doubt pushed upward to a considerable extent. At the time of the appearance of these intrusions the previous rocks had become profoundly changed in character, so that they were much in their present condition. The district embracing Essex, southern Franklin and northern Hamilton counties felt the full force of this invasion, the larger part of the present surface rocks in that district consisting of these igneous rocks, while away from it they occur merely in patches. The present rocks cooled far beneath the old surface and have been brought to the present one by wear and removal of the overlying rocks. They represent abyssal, cooled masses, whence no doubt much molten material ascended toward, and not improbably to, the old surface.

These rocks may be grouped into four great classes, anorthosites, syenites, granites and gabbros, all undoubtedly derived from some great parent molten mass below by some process of differentiation. The anorthosite intrusion was the first, the bulkiest, and is the only one whose precise limits have so far been worked out. It was followed by one of syenite, that by one of granite, and the gabbro intrusion seems to have been latest of all.

All three have a much wider range and a more patchy distribution than the anorthosite. Their precise importance is however uncertain, since there are certainly granites and gabbros, and likely syenites also, of more than one age in the region, though quite similar to one another, so much so that no criteria have yet been developed for their discrimination. This difficulty has not to be met in the case of the anorthosite.

At some time after the cooling of these great intrusions the whole district was subjected to great compression, as a result of which all the existing rocks were profoundly changed in character, the intrusives as well as the older rocks. But, since the igneous rocks did not experience the earlier compressions, as did the others, and since these must have been profoundly affected by the heat and pressure of the intrusions themselves, the intrusives are less completely altered than are the older rocks, and frequently retain traces of their original structures and textures, often in considerable amount, so that usually their origin and nature are not open to question. This is specially true of the anorthosites, which are mostly very coarse grained, porphyritic rocks, but it is frequently true of the others also. The rocks were more or less mashed and recrystallized, and rendered gneissoid in greater or less degree, the same rock varying much from place to place in these regards. It is the more gneissoid phases which are most difficult to distinguish from some of the older rocks.

The character of the changes produced indicates that the rocks were under great load during the compression, or, in other words, were deeply buried beneath overlying rocks.

Great Precambric erosion. Precambric time was very long, not improbably comprising as much as or more than one half of the earth's geologic history. During most or all of the later part of this vast time interval the region was a land area and undergoing wear. The overlying great thickness of rock under which the present surface rocks lay buried at the time of compression, was removed in Precambric time in greater part. Quite likely the time of elevation into a land area coincided with the time of compression, the two being effects from the same cause. The great

igneous intrusions may also have aided or initiated the upward movement. The great thickness of rock removed indicates the probability of more than one upward movement, since it is unlikely that the region ever had an altitude equal to the bulk of removed rock. Periods of depression beneath the sea may have alternated, though it is improbable that these could have had any great duration, or we should surely find traces in the region of the deposits formed, and these we do not find. It is impossible to state positively the amount of rock removed during this great denudation, but in all likelihood at least from 3 to 5 miles of rock thickness were worn away from the surface, and perhaps considerably more, specially locally.

Surface topography at the close of the erosion interval. The land surface left at the termination of this long period of wear is of such nature that it could have been produced in no other way than by long protracted erosion under conditions of stability of level. After the last uplift of the region the streams sawed their valleys down to grade; and the slow processes of valley widening continued at their work of broadening the valley bottoms and narrowing the upland divides between the valleys, till the latter were largely obliterated, and the resulting surface was one of small relief, broad, shallow valleys, largely adjusted to the weaker rock beds and structures, separated by low, gently sloping divide ridges, with occasional low, rounded hills of extraresistant rock protruding above the general level, with elevations of only a few hundred feet above the valley floors as a maximum. To produce a land surface of this sort, specially on such resistant rocks as those of the Adirondacks, requires a vast lapse of time. The surface was not equally planed down in all parts of the region, but was somewhat more irregular on the present northern and eastern borders than on the southern and western, though the discrepancy is not marked. Over much of the surface the rocks were deeply weathered and decayed, forming a deep soil, but the evidence in this regard is conflicting, and apparently decay was less advanced on the northeast than elsewhere.

Later Precambric disturbances. During the long Precambric erosion period the present surface rocks were gradually approaching the surface as the overlying rocks were, bit by bit, removed. They were therefore under progressively less and less load of overlying rocks, and, if subjected to compression during this stage, the effects produced would be very different from those brought about by compression under great load. That the rocks were so affected when much nearer the surface is clear, the main result being the production of the highly inclined or vertical, rather even cracks or fissures known as joints. There have been later times of joint formation in the region also, and the different sets are difficult of discrimination. But it is clear that there was some development of joints and faults, indicative of stress, at this time.

Late Precambric igneous activity. During most of the long period of denudation which followed the time of the great igneous intrusions there was an absence of igneous activity in the region, at least in so far as near surface effects were concerned. But toward the close of the period, when the present surface rocks were no longer deeply buried, but were comparatively near the surface, molten rock again came up from beneath, likely from the same source whence the material of the great intrusions sprang. Whether any of this molten rock reached the surface then existing can not be determined, since no vestige of that old surface now remains, but in all probability there was volcanic action at the surface. The lavas utilized a system of east and west fissures or joints as their channels of ascent and eventually cooled and solidified in them. Such lava-filled fissures are known as dikes, and these dikes are very numerous in portions of the region, specially at the northeast. Their upper parts, along with their surface outpourings, were worn away long ago. Could they be followed in depth, they would lead eventually to the reservoirs which supplied the material with which they are filled.

There are two sets of these dikes, showing that there were at least two separate periods of igneous action at the time. The more common dikes are of heavy, dense, black rocks of the sort known as diabase. The others are less dense and heavy, usually

of red color and have the composition of syenites and granites. The latter are somewhat the older. The northeastern Adirondacks were the main scene of this igneous activity. The red dikes are practically confined to Clinton county. The black dikes are much more numerous and have a much wider range, but are vastly more abundant in Clinton and Essex counties than elsewhere.

Erosion still continuing after the close of the igneous activity, all vestiges of the surface volcanics disapppeared, along with a thickness of rocks of considerable amount, but to be measured in hundreds, rather than in thousands of feet.

Early Paleozoic history

The long period as a land area finally came to an end, a movement of subsidence was initiated in the region and it became depressed, slowly passed beneath the level of the sea and began to receive deposit on the rather evenly worn surface, the valley bottoms necessarily passing beneath the sea before the low divides were overtopped. This subsidence began at the northeast and slowly progressed southwestward. As zone after zone came within reach of the cutting of the waves, they would tend to pare it away to a smooth surface, and in parts of the region this wave action may have been a considerable factor in evening it. As zone after zone passed beneath the sea, deposit would commence on the surface, and, as the subsidence began on the east and northeast and progressed westward and southwestward, deposits of progressively younger and younger age appear resting on the old land surface in passing from east to west, producing what is called overlap. Because of this, the earliest paleozoic deposits, those of Lower and Middle Cambric age, do not appear about the Adirondack region at all, though found not many miles to the eastward, where they were deposited in a separate basin. Because of this, the Potsdam formation, or Upper Cambric age, does not appear on the west and south of the Adirondack region, though in great force on the north and east.

Potsdam formation. This coarse, often pebbly, massive sandstone deposit was the first formation laid down on the old land

surface of the present Adirondack region. It was deposited in shallow water under conditions of sufficiently vigorous wave and current action to remove all fine mud particles, which were swept away and deposited elsewhere in deeper water. In Clinton county a thickness in excess of 800 feet, perhaps more than double that amount, of this sand accumulated before changing conditions brought about a change in the character of the deposit. The water must have been shallow throughout, hence the rate of subsidence could not have exceeded the rate of accumulation. This thickness diminishes westward and southward, and the sands are mostly absent from the west side of the region, as has just been stated. With diminishing thickness, it is apparently the lower beds that disappear. The basal portion of the formation in Clinton county seems to be the oldest of the deposits in the Adirondack region, and its often coarsely pebbly character and abundant content of undecayed feldspars indicate vigorous wave action on rocky shores of resistant, unrotted rocks. The upper portion of the formation here, and most of it elsewhere, consists of pretty pure quartz sand, indicative of prevailing different conditions from those above, namely that either the feldspars had been pretty thoroughly rotted previous to submergence, or else that they experienced the triturating action of the waves for a sufficient length of time to be wholly ground fine, while the somewhat harder quartz yet remained coarse, implying a slower rate of subsidence. The former is much the more probable cause, though no doubt the latter had some influence also.

The present Adirondack region must have supplied much of the rock material thus spread on the sea floor, and the drainage of the district must have been mainly to the north and east. The present western border of the region was but slightly submerged during this time, and for part of the time the waters were clear, with deposit of limestone instead of sand. The upper part of the formation around the Adirondacks is certainly a marine deposit and holds marine fossils. These are lacking in the larger part of the formation, and this, together with its character, sug-

gests the possibility that the larger part of the formation on the north was deposited in a closed or nearly closed basin.

Beekmantown formation. By the close of Potsdam time the sea had encroached for a considerable distance on the present northern and eastern portion of the Adirondacks, but there was yet a large land area remaining in the heart of the region which on the west and southwest extended somewhat beyond the present surface limit of the Precambric rocks in these directions. During Beekmantown time submergence was in progress on all sides of the Adirondacks, but it was most rapid, and to greatest amount on the northeast and diminished to the south and west, the rocks having treble the thickness in the lower Champlain valley that they have along the Mohawk. On the extreme west the amount of subsidence was but slight and little deposit took place.

The Beekmantown rocks are in large part peculiar, and except for the fact that they are clearly water-deposited rocks, the precise conditions under which they were deposited are difficult to understand. In the upper portion of the formation are many pure limestone beds, often containing numerous fossils, and so far as these are concerned the formation seems clearly a marine limestone. These beds seem to be limited to the east and north sides of the region and to be wholly lacking on the south and west. The bulk of the formation everywhere is made up of beds of sandy dolomite. The sand is mostly rather coarse and is embedded in a fine mosaic of crystalline dolomite. There is little mud in the formation and fossils are either wholly lacking or else exceedingly rare. The sands imply vigorous water action, sufficiently so to transport them to their present resting place and to wash away all fine mud. Yet the sand forms less than 25% of the whole formation, the bulk being dolomite, along with some calcite. The nature of the deposit would suggest a chemical, rather than an organic origin for this material, since the waters must have been shallow, and this would imply estuarine or closed basin conditions of deposit, stream waters holding lime

and magnesium carbonates in solution, with frequent storm waters sweeping in sands from the adjacent land, and likely a climate of some aridity. That is, there must have been a land barrier to the eastward separating the basin from the Atlantic, and another to the westward shutting it off from the interior sea, with a considerable Adirondack island in the midst of the sea, on whose slopes the different beds of the formation overlapped as subsidence progressed. The whole subject is beset with difficulty and needs thorough investigation, something that it has not yet received.

Because of the greater thickness of the formation in the Champlain valley, and because the upper marine limestones occur only there and on the north, it is reasonable to suppose that the subsidence here opened a northeasterly connection with the sea, whence the marine forms entered the basin. Likely at about the same time subsidence ceased on the south and west and was not improbably replaced by uplift, raising the region above sea level and preventing the deposit of the marine limestones there. Such an uplift certainly occurred shortly after, and may well have begun then.

As a result of the Beekmantown subsidence and deposit, the land area of the Adirondacks was much diminished in size; though there still remained an area, mainly on the south and west, which was not submerged. Then came the uplift, which much increased the extent of this land to the south and west.

Chazy formation. In the Champlain valley the Beekmantown formation is overlain by a considerable thickness of mostly quite pure, marine limestone beds containing abundant fossils. Followed to the north into Canada, these deposits change into sands and muds to a considerable extent, showing that a land area which supplied this land wash must have existed in that direction. How much of the present northern Adirondack region was overspread by the Chazy sea can not be told, but it would seem that it must have been mainly submerged, since no land wash from it reached the present Champlain valley region. Followed to

the south, the Chazy deposits rapidly thin out, and the formation was not deposited on the south and west sides of the region at all. Subsidence thereabouts must therefore have intermitted during Chazy time and likely during the latter part of Beekmantown time as well. In fact, the downward movement seems to have been replaced by one in the contrary direction, bringing above sea-level an area of considerable, though unknown, extent to the south and west of the Adirondacks, a condition in which it remained throughout Chazy time. The altitude above sea-level must have been very slight, since the surface shows little sign of wear.

The Chazy basin then spread over the north and east sides of the region only, its open water connection being with the eastern, and not with the interior sea, the extent of the latter being considerably contracted during this time.

Lowville limestone. This is a comparatively thin band of pure limestone which directly overlies the Beekmantown on the south and west sides of the Adirondacks, but does not appear at all on the north and east. The Chazy elevation on the southwest was terminated by depression, and at about the same time or previously, elevation occurred, draining the sea from the Chazy basin. The Lowville is plainly unconformable to the Beekmantown surface, varies much in thickness and is wholly wanting in places, evincing the irregularity of surface on which it was laid down.

The conditions under which the Lowville was deposited did not permit the entrance of, or else were unfavorable to the life of a marine fauna. If the former be the explanation, there must have been a land barrier between it and the sea to the south; if the latter, the cause is purely conjectural. Certainly the rock is very barren of fossils for the most part.

Black River and Trenton formations. Both the Chazy formation on the northeast and the Lowville on the southwest are overlain by a series of limestone beds which are plainly of marine origin, showing that following the Lowville, subsidence was

inaugurated all about the Adirondacks causing the interior sea to spread northward and eastward over the entire region. The Black River is locally absent along some of the southwest border, owing to slight irregularities in the floor on which it was laid down, and less frequently some of the basal Trenton is absent from the same cause. Whether these irregularities were due to wear or to slight folding has not been determined.

While apparently some slight remnants of the old Adirondack island persisted above sea-level during the whole or part of the Trenton, it is probable that they were of insignificant extent and likely confined to the southern part of the region. With these possible exceptions the sea of the closing Trenton seems to have overswept the entire Adirondack region.

The Black River and Lower Trenton are quite pure limestone deposits and hence clear water formations. But the Trenton soon comes to show some mud admixture, at first slight and intermittent but slowly increasing in amount, till finally it equals and then exceeds the lime, and the deposit becomes a calcareous shale rather than a limestone. These muds came from some land area to the eastward and progressively invaded the sea toward the west, so that limestone was still in progress of formation on the west while shales were forming to the east.

Utica formation. The limestones of the Trenton pass gradually upward into shales through increasing invasion of mud from the east. Trenton submergence was much interrupted on the south and southeast, so that the formation is much thinner there than on the west and the northeast. In the latter locality the greater thickness is likely due to more rapid, or to less interrupted subsidence. On the west it is, at least in part, due to the gradual encroachment westward of the muds. Eventually however the conditions of mud deposit held sway over the entire region and far beyond. The sea was not deep, and the muds were swept in by currents moving toward the southwest. Subsidence was considerable, so that several hundred feet of shales accumulated in nearly all parts of the region, and in some portions a much greater thickness.

This submergence apparently completely overswept the old Adirondack island, and that for the first time in its Paleozoic history, with the possible exception of the latter part of the Trenton. The whole of New York State would seem to have been submerged and that for the last time in its geologic history.

Later Paleozoic changes of level

Toward the close of Utica time subsidence became again interrupted and an upward movement was initiated. It was first felt on the northeast, bringing the northern Adirondack region again above the sea, and it has in the main remained a land area from that time to the present. The movement of elevation progressed to the south and west till all of eastern New York had been brought above sea level. From this time on the oscillations of the southern and western borders of the present Adirondack region now admitted the sea to unknown distances on the flanks of the region, now again excluded it. Thus the Medina, Clinton and Helderberg seas of the Siluric and Devonic quite certainly overlapped the margin of the region to some extent, and later Devonic seas may well have done likewise. The district was near the shore line of those seas, alternately received deposit and experienced wear as the position of the shore line fluctuated. The truncated edges of the deposits of those seas now come to daylight to the south of the Mohawk valley in successive order of deposit, their formerly existing extensions northward having been worn away. Hence, while it is obvious that they formerly extended considerably north of their present limits, the amount of such extent is purely a conjectural matter.

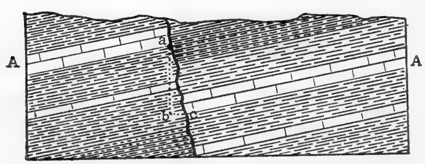
While the sea border was hugging the south and west sides of the region, the remainder was out of water and so continued with the possible exception of the submergence of a Champlain valley strip during Helderberg time. Such a submergence is very probable, but the amount of area so depressed is purely conjectural, the deposits of the time having utterly disappeared, owing to subsequent erosion. This is, so far as known, the only time that any portion of the northern Adirondack region has

been beneath the sea since the close of the Utica, except for a submergence of the Champlain valley in very recent times. In all likelihood it was a depression of a channel, rather than of a wide area.

Paleozoic disturbances

Aside from the repeated oscillations of level in the region during Cambric and Siluric times, which have just been outlined, there were periods of more considerable disturbance. Following Utica deposition and uplift there came such a time. Compression acting from the east effected the elevation of the Taconic range with some folding and fracturing of the rocks, and in a minor way the Adirondack region was affected. Again toward the close of the Paleozoic the stresses which produced the folding and uplift of the Appalachian region must have been felt in this region also. Not unlikely there were other times of lesser stress. The effects produced on the rocks of the region during these various times were the same in kind, and, though the sum total of all can be recognized, the relative amount to be ascribed to each period can not be ascertained. The main results were the production of faults and joints in the rocks.[1] Minor undulations, or folds, were also produced, but these are relatively insignificant and entirely subsidiary to the other effects. The eastern Adirondack region by no means felt the full force of either disturbance, and in the west the effect was much less than in the east. The major line of both disturbances swerves round, and approaches the region most nearly at its southeast corner.

[1] A fault is produced by a sliding movement of the rocks on opposite sides of a fissure, with the result that the same rock stratum is higher on one side than on the other, as illustrated in the accompanying diagram. The stratum AA has been dropped on the right side of the fault relative to its position on the left side. The distance *ac*, measured along the fault plane, is called its *displacement*, the vertical distance *ab*, that separates the two ends of the stratum, is called the *throw*, and the horizontal distance *bc* is the *heave* of the fault.



The main faults of the region run across it with a general n.n.e.-s.s.w. course, but they curve repeatedly, and a given fault seldom holds a given direction for any great distance. In nearly all cases the dropped block is on the east, and the raised block on the west side of the fault plane. The resulting topography must have consisted of relatively narrow platforms terminated westward by cliffs of varying hight, depending on the throw of the fault concerned, rising to the level of the next platform above, the whole with a general n.n.e.-s.s.w. trend. Thus seems to have been produced for the first time the considerable and rather abrupt difference in level between the Adirondack region and the Champlain valley. The eastern Adirondack region was thus given a considerable elevation, with a rapid, steplike fall to the eastward and a gentler and steadier slope to the west.

Some few of the faults downthrow to the west instead of the east, producing between such a fault and the next easterly throwing fault to the westward a depressed block or valley with steep inclosing walls on both sides.

In addition to the main faults are a multitude of minor ones grading down to the merest slight slipping along the joint planes. Many of these are cross faults of considerable magnitude, making large angles with the main ones, and cutting up the main platforms into a series of segments at various levels.

It is likely that most of these faults date from the time of the Appalachian uplift of the late Paleozoic. A beginning may have been made by the Taconic disturbance.

Paleozoic igneous activity

Initiated possibly by the disturbances which effected the elevation of the Taconic mountain range, though more likely of late Carboniferous date, came renewed igneous action. Here again all traces of surface volcanic action, if there was such, have been removed by subsequent wear, and the only signs of the activity which remain are the old, lava-filled channels of ascent, the dikes, together with a few larger masses, which paused before reaching the surface and crowded out a place for themselves by squeezing

laterally between the rock layers, and bodily raising the overlying rock. Here again we find two sharply contrasted sorts of lava, one light colored and difficult to render thoroughly fluid, the other black and fusing at a much lower temperature. Here again the black rock is much the more abundant and with wider distribution. But here such evidence as there is shows that the black rocks were the first, instead of the last to appear, as in the case of the late Precambric dikes.

In New York these rocks are confined to the near vicinity of Lake Champlain, in Essex and Clinton counties. Apparently the Adirondack region was on the extreme edge of the district affected.

In the Mohawk valley and westward, occasional dikes are found of a very different character from those along Lake Champlain, which are perhaps younger than they are and represent intrusions from a different source. They are so few in number and so scattered that they indicate only a trifling amount of igneous activity. If there can be said to be any well marked center of action at all, it was about Syracuse. If there were any surface volcanos, they must have been few and small.

Paleozoic erosion

Throughout the latter part of the Paleozoic the Adirondack region was a land area, and, if the assumption that a considerable amount of the faulting of the region dates from the time of the Taconic disturbance be correct, this land area had a considerable elevation on the east and northeast, diminishing gradually to the west and south, with the Champlain valley outlined as a result of the faulting. The time involved is great, several millions of years at least, and a large amount of erosion must have been accomplished, specially on the more elevated areas. The cover of paleozoic deposits must have been swept away over a considerable portion of the interior region, where it was thinnest, and the general surface much evened by erosion. So far it has been found impossible to separate this erosion interval from that which followed, so far as results are concerned. All of the surface left by

the former seems to have been removed later, and it can be simply inferred that much wear took place. In all probability the great Appalachian disturbance, near the close of the Paleozoic, must have been strongly felt, causing renewed movement along the fault planes provided they were in existence, and a considerable increase in the altitude of the region.

Mesozoic history

During early Mesozoic times there were disturbances of considerable amount in the eastern part of the country, whose effects may well have been felt in the Adirondack region. A subsidence of long, narrow troughs, parallel to the general trend of the Appalachians, took place; deposits accumulated in these troughs, often to very considerable thickness; large quantities of quite fluid igneous rock ascended from below, in part reaching the surface as great flows, in part thrusting a way between layers of the accumulated sediments as interbedded sheets; faulting on a large scale followed, breaking up the surface into a great mosaic of fault blocks. It is quite possible, nay probable, that further movements took place along the Adirondack faults at this time, and additional faults may have formed. It is also possible that, because of downfaulting, deposits may have accumulated in the Champlain and upper Hudson valley troughs. Evidence has recently been forthcoming of volcanic action, probably of this date, on the immediate southeast margin of the Adirondack region, and the future may bring to light similar evidence elsewhere.

However this may be, the further faulting would have produced additional elevation of the Adirondacks with increased altitude above the Champlain valley, and inaugurated another period of active erosion tending toward a new and lower base level. On the mosaic fault blocks of the valley the amount of possible erosion would largely depend on relative altitudes, and great variation in the amount is to be noted on adjacent blocks, Potsdam, Beekmantown, Chazy, Trenton and Utica rocks, even Precambric as well, all being found as surface rocks near the lake level today, often in close proximity. Where Utica rocks are at the surface, the

total amount of wear since Utica time has been exceedingly small, and the surface must have been for much of the time near base level. Moreover, such blocks were the most downfaulted of all and must have formed depressed basins with every period of renewed faulting, as such receiving deposit from the surrounding higher blocks as these were worn down, thus protecting their own surfaces from wear for long intervals.

This erosion interval was so protracted, extending through the greater part of Mesozoic time, that the whole region was finally planed down to a surface of little relief, broad shallow valleys and low divides, with occasional low, rounded hills or clump of hills where extraresistant rocks occurred, or where favorable location prevented maximum wear. The fault cliffs, or scarps, were entirely wiped out as topographic features, the raised side being worn down to the same level as the dropped.

In the southern and western Adirondack region this old surface is still recognizable, as the upland surface into which the present valleys are cut, the old residual hills rising above it now as they then did. The present plateau upland of southeastern New York would seem to represent a continuation southward of this same old surface; and, if this be the case, the result in the Adirondacks was simply a local development of conditions which prevailed widely in the eastern United States at this time.

Cenozoic history

This long period of quiet wear was terminated by another uplift, which would seem to have occurred at the close of Mesozoic, or the beginning of Cenozoic time. This uplift inaugurated another erosion cycle with a much lower base level. In the Adirondack region this uplift was, at least for the northern part of the district, of a dome-shaped character, the major axis of the dome being along a nearly north-south line closely coinciding with the line between Clinton and Franklin counties, thence turning southwestward; the minor axis running through the extreme south of Franklin county and thence eastward through Essex. In the eastern Adirondacks this uplift was complicated by further shifting along the fault planes, bringing fault cliffs, or scarps, again

into prominence as topographic features; reelevating anew the eastern region as contrasted with the Champlain valley, and reproducing the comparatively rapid, steplike drop from one to the other; and breaking up the old, comparatively even erosion surface into a jumble of disconnected blocks at various altitudes. Hence the present ridge and hilltops appear at all sorts of discordant elevations, instead of exhibiting the concordance in altitude which is such a characteristic feature on the south and west, where there was little or no faulting.

Not far to the west of the main axis of uplift lies a central depressed belt whose ridge summits fall far short of attaining the elevations along that axis, and much short of attaining those to the west. These differences are most accentuated through Franklin county, and the belt seems to have originated as a depressed, or dropped fault block, between the eastern and western uplifted areas. Whether it originated at this time, or dates back to a previous period of faulting, with renewal of its previous features at this date, can not be told.

The region remained at the new altitude given by the uplift for a sufficiently long time (the greater part of the Cenozoic) to permit of erosion giving it approximately its present relief. Stream valleys were cut down to the new base level and on the average sufficiently widened, so that one half of the region (at a rough approximation) was cut down well toward that level, the remainder forming interstream ridges and hills whose summits have been lowered little below the altitude given them by the uplift. The streams had become adjusted to the rock structure of the region during the previous cycles of erosion, so that they coincided with, and their attack was mainly felt on, the weaker belts. In the heart of the region, where Precambric rocks are at the surface, the weaker rocks are the Grenville limestones and associated sedimentary gneisses. Wherever these rocks occurred in belts of any extent, they would locate the line of a stream valley, whose width would be rudely proportional to the breadth of the belt. The remaining common rocks of the region are much more resistant and with no great variation among themselves in this respect, so that they present little compara-

tive inducement to valley-making, and the principal remaining lines of weakness are structural, lines of faulting and of repeated jointing. The main joint directions vary somewhat in different parts of the region, but there is always an important set with a direction approaching parallelism with that of the main faults, and many of the main valleys of the region have this trend, this being specially noteworthy in the eastern district where faulting has been most pronounced.

Because of the dome-shaped character of the uplift, the tendency has been to locate the main watershed of the region at its apex, with a radial arrangement of the main streams with respect to it. Moreover, since the sides of the dome have a slightly greater slope than the graded slope of the streams, the valleys are cut to greater depth in the heart of the region than on its flanks. The vertical distance between the old and new base levels is greatest there.

When we pass to the Paleozoic rocks which everywhere surround the region, dipping slightly away from it, the stream adjustments necessarily differ, owing to the different character and arrangements of the rocks, which lie with their exposed edges parallel to the border of the region. The original radial streams flowed across these beds, but the tributaries which developed to these radial streams flowed along them and would develop mainly on the softer belts. With successive uplifts of the region, these adjusted streams would be more advantageously situated than many of the radial streams, and would increase in size at their expense, converting them into tributaries. This process has had much to do with the production, on all sides of the region of main drainage valleys parallel with its sides, though by no means the only factor involved.

Glacial history

This long erosion period was terminated by the great change in conditions which ushered in the Glacial period. The long and complicated history of the region during Glacial times is but imperfectly known. It was well within the field of action of the

great Labrador ice sheet for a long time. From analogy with other regions it may be inferred that there was more than one advance and retreat of ice sheets over the district, but how many and how extensive are purely conjectural matters for the immediate region. The last ice advance destroyed, for the most part, the traces of the presence of its predecessors.

Coming down on the region from the north and northeast, the Labrador ice sheet had its advance opposed by the elevated mass of the Adirondacks and was forced aside by it into two great ice streams which worked their way around the region. The one advanced up the St Lawrence valley and turned south along the west side of the Adirondacks, and thus reached and entered the Mohawk valley from the west; the other moved south through the Champlain valley, reaching the Mohawk at the east end. As the ice increased in thickness, it encroached more and more on the flanks of the region till finally it overswept the whole, and persisted in this condition for a long time. While the basal currents of the ice continued to be controlled by the topography, the main mass swept over the region in a general southwesterly direction. Ultimately changing conditions brought about recession. The thickness was least over the highlands, and the ice would first disappear there, leaving the two great currents sweeping round the region, as they did during the advance. These slowly dwindled and disappeared northerly.

The final disappearance of the ice left the topography modified both by glacial wear and glacial deposit, but with its larger features little changed. Ridge slopes were smoothed, summits rounded, valleys clogged with deposit, lakes produced either by inequality of deposit or by local excessive downward erosion, stream courses more or less modified, a host of minor changes much altering the appearance of the region.

Postglacial history

During the continuance of glaciation changes in altitude took place, and at the time of final melting away of the ice from the St Lawrence valley the elevation was much less than at the beginning of glaciation, was in fact sufficiently low to enable the

sea to run up the valley into Lake Ontario and to invade the Champlain valley also, producing a huge, branching estuary. In these waters marine sands and clays were deposited, and, though unconsolidated, these still remain in considerable bulk, their marine origin distinctly shown by the marine fossils which they contain.

Gradual elevation of the region since, greatest at the northeast, and amounting to about 600 feet at the lower end of Lake Champlain, has brought the region above sea level and shrunk the St Lawrence estuary to its modern proportions. This upward movement is probably still in progress.

But a few thousand years have passed since the ice disappeared. Erosion has made but little progress in obliterating its traces except along the immediate stream valleys. Since the streams have been more or less shifted from their preglacial courses, they have been obliged to recarve their valleys in whole or in part, and they are actively at work at this task. The steady rise of the land in postglacial times has given them a steadily lowering base level, and, though they have cleared away much of the glacial deposit from their paths, the amount of rock cutting done is not great.

THE ROCKS

Precambric rocks

While in many parts of the Adirondacks areas of varying size are found in which the rocks that occur may be unhesitatingly classed as Grenville sediments or as later igneous intrusions, over much of the district this is not the case, but an intimate admixture of various rocks is found, in apparently hopeless confusion. Thus we find Grenville sediments elaborately interbanded with other rocks, apparently igneous, yet seemingly conformable with them as an integral part of the series. We also find rocks which are not to be distinguished in appearance or in composition from the rocks of the great intrusions, except for perhaps a more thoroughly gneissoid character, and yet so interwoven with other rocks, so far as yet known not represented in the great intrusions, that it hardly seems possible that the two can belong together. There are also considerable areas of gneisses which are quite like

the uncertain gneisses involved often with the Grenville rocks, yet without any Grenville admixture, and the relationship of such rocks forms a very difficult problem. The Grenville belts and patches and the areas occupied by the later igneous intrusions have been in the main discovered and mapped. There yet remains the exceedingly difficult problem of the separation of these mixed belts into their several elements, and the working out of their affiliations. This is likely in many cases to prove impossible, and in nearly all cases the amount of intermingling is so great as to render attempts at detailed mapping of the several elements futile, and to require their designation as belts of mixed rocks.

Grenville rocks. The most characteristic of these are the limestones. They are always thoroughly, and usually coarsely crystalline marbles, which even when purest contain scales of graphite. They vary greatly in purity and usually contain green and white pyroxenes, apatite, phlogopite, quartz and scapolite, often in large quantity. In the thick beds these are more apt to be concentrated in the outer portions, in fact the limestone often grades into a pyroxene quartz rock, with or without scapolite, or else into a nearly pure pyroxene rock. Some beds of apparently pure limestone are found to contain a large quantity of white pyroxene, and when this has altered to serpentine, as it tends to do, the white and green mottled, calcite serpentine rock known as ophicalcite results.

There is always found associated with the limestones a series of curious schists and gneisses, often found also where no limestone is present, which are difficult to describe, owing to their many phases, but which are easy of recognition and are as characteristic of the series as are the limestones. They vary from exceedingly quartzose to quite basic rocks. Garnet, graphite, sillimanite, pyrite and white pyroxene are very frequent and characteristic minerals. Many of the beds, specially those which contain pyrite, weather readily to a peculiar, rusty looking rock, seemingly much more altered than is actually the case. Many others are exceedingly quartzose, so much so as strongly to resemble quartzites, but these are found to contain usually much alkali feldspar, rocks that

contain more than 75% of quartz being uncommon. Locally recrystallization has produced very coarse grained varieties of these rocks, the quartz appearing in large sheets and bunches. But such are usually interbanded with layers in which much pyroxene is associated with the quartz.

Garnet is often a very abundant mineral in these rocks, though more abundant in the more feldspathic varieties than in those purely quartzose. Graphite is more apt to appear in the rusty-weathering gneisses. In certain beds garnet becomes the predominant mineral, but these make small bulk in the series as a whole. Sillimanite is also found mainly in the quartzose gneisses, perhaps specially in those rich in garnet. At times it is only sparingly present as microscopic inclusions in the quartz, at other times it becomes quite abundant and is in larger needles.

In the more basic gneisses pyroxene is usually the most abundant dark mineral, though biotite and phlogopite micas are also frequent, some very micaceous bands occurring. Aside from frequent narrow bands of amphibolite, hornblende is a relatively rare mineral in the Grenville rocks. These amphibolites may be sedimentary, but seem to the writer more likely to represent original igneous dikes or sheets intruded into the series. Since, however, there is considerable variation in their appearance and make-up, they may be partly of one origin and partly of the other.

These Grenville rocks have the composition of sandstone, shales and limestones and their intergradations, and have a wholly different mineralogy from any known igneous rocks, whether metamorphosed or not. Under metamorphism they seem to have wholly recrystallized and to have been greatly stretched in one direction, giving rise to the foliation, and drawing out such igneous rocks as had been intruded into them into parallel bands with a foliation in common with them. The limestones were the most plastic of the beds under metamorphism, and, where the rocks have been most compressed, have often been so squeezed as to comport themselves much like igneous rocks, pressing into fractures in, and inclosing a number of fragments of, the more brittle inclosing rocks, producing combinations which have a strong external

resemblance to conglomerates. To a minor degree the same sort of thing is shown in the gneisses, two adjacent bands of different brittleness showing the more brittle ruptured and the other squeezed into the break. This has often happened to the basic bands in the acid gneisses for example. On a yet smaller scale it is often shown among the various minerals of a single rock.

Along the eastern border of Franklin county, extending northward for a few miles from Franklin Falls, are considerable masses of a coarse, rusty brown rock which consists of little else than quartz and microperthite feldspar. The quartz is in flattened lenses or spindles up to an inch or two in length, all with the same orientation, and surrounded by a mosaic of microperthite. The belt adjoins a belt of Grenville rocks which includes limestones; and Kemp interprets the rock as a recrystallized and squeezed conglomerate.[1] While this view may be the correct one, it is desired to call attention to the fact that the belt is also in close association with a mass of augite-syenite belonging to the later eruptive series, that much of this rock possesses the same spindle quartz, and that much of it consists of little else than feldspar and quartz. The resemblance is so close that the writer's disposition has been to refer the rock to these syenites, as a somewhat aberrant member, and this alternative view is thought worthy of record.

In nearly all exposures of the Grenville rocks there is found an admixture of red, gray and black gneisses which have the composition of igneous rocks, granites, syenites, diorites and gabbros and are thought to be such in a much metamorphosed condition, though for the most part they have lost all trace of the structures and textures of such rocks and possess an evenly granular texture, due to thorough crushing or granulation of their minerals, accompanied by a certain amount of recrystallization. They now form red, orthoclase gneisses, amphibolites, and gray to black, granular gabbroic gneisses. They are usually so involved and interbanded with the sedimentaries as to appear

[1] Am. Ass'n Adv. Sci. Proc. 49:169.

bedded and like an integral part of the series. But their composition and character seem to point to the igneous origin of a large part, if not the whole, and they likely represent dikes, sheets and small intrusive masses, somewhat later than the sediments.

All these rocks are often cut by rusty looking amphibolite dikes which cut across the foliation, and represent somewhat later intrusions, likely of diabase, but so old and profoundly altered as to present little resemblance to the original rock except in composition.

These gneisses are further cut by yet later granites and gabbros, rocks which have not been so profoundly metamorphosed, but which still retain sufficient traces of their original structures as to render their origin certain. The finding of these is quite what should be expected, since all younger igneous rocks must have cut their way through these gneisses in working their way toward the surface.

At the present day the Grenville rocks are found in numerous long, narrow belts around the borders of the Adirondacks, but mostly only in small, disconnected patches in the heart of the region. The reasons for this will appear later, but in a word it seems due in large measure to the greater amount of erosion which the Precambric rocks have undergone in the latter situation. The belts are larger and more numerous on the south and west sides, and are infrequent on the north, except at the extreme northwest. Kemp has emphasized the greater abundance of limestone in the belts on the west and the greater quantity of quartzose gneisses on the east. In the large way this is the case, though both rocks are found in each locality. Both are also found in the scattered patches which extend through the heart of the region.

The base and summit of the Grenville are both unknown, and the thickness of the series is therefore purely a matter of guesswork. The rocks were deposited all over the region, but erosion has removed all but the present belts and patches. The lack of

summit to the series is therefore what would naturally be expected, and it may be legitimately argued that the thickness must have been very great, since so great an amount of rock has been worn away. It is by no means meant to imply that these rocks formed the whole mass of what has been removed, but it is thought that they must have constituted a respectable percentage of it. Even the remaining fragments indicate a very considerable thickness for the formation.

The nondiscovery of the base is not so easily accounted for. It is a water-deposited formation and must have been laid down on some floor, and it would naturally be expected that some evidence of what this floor was would be forthcoming. But the great metamorphism which has destroyed the old rock structures and given them a common foliation, the inextricable intermingling of igneous rocks with the Grenville sediments, and the later great igneous invasions from beneath have so disguised the rock relationships as to make it very likely that the base of the Grenville will never be satisfactorily made out in the region.

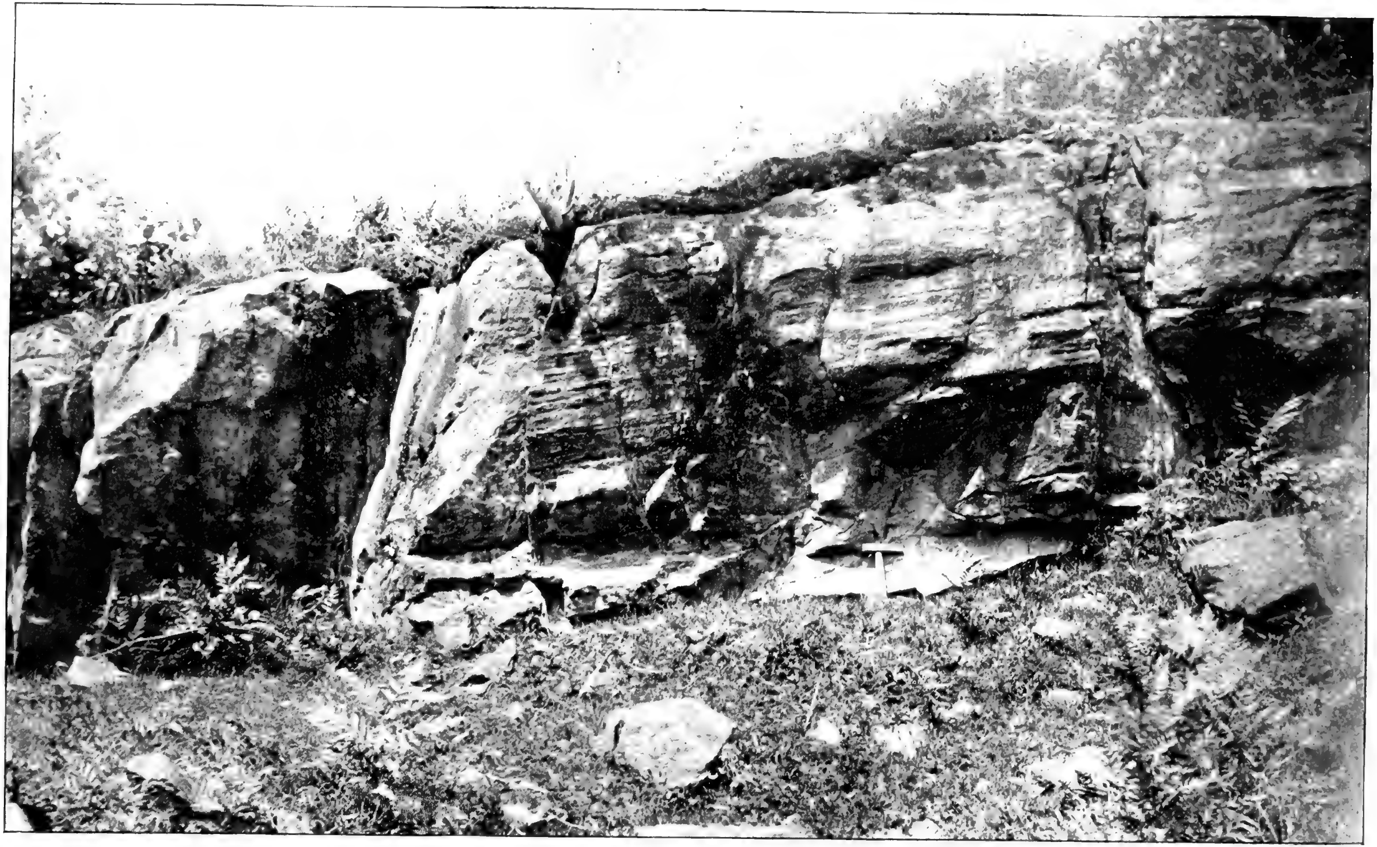
Doubtful gneisses ("Saranac" formation). In the portions of the Adirondack region with which the writer is familiar the only large body of gneiss which is practically free from all Grenville admixture and at the same time seems to have no connection with the later igneous intrusions, is found in a belt running through northern Clinton and Franklin counties, adjoining the Potsdam boundary. It is not utterly free from Grenville rocks, since a few small patches of these do occur, though unfortunately exposures which disclose the relations between the two nowhere appear. The presence of these few small patches in the great body of gneiss furnishes one of the main arguments for the distinction between the two, since it is unlikely that the distinctive Grenville rocks would be present in such slight quantity were the gneisses affiliated with them, that is, were either sediments or were igneous rocks of Grenville age.

These gneisses are prevailingly red, acid gneisses whose usual feldspar is orthoclase (or microperthite or microcline), and which

have the composition of granites. They vary much in coarseness from place to place and from band to band, ranging from finely and evenly granular varieties (which are the prevailing ones) to those which are quite coarsely crystalline. An alkali feldspar (microperthite, microcline or orthoclase in order of abundance) and quartz are the prevailing minerals, magnetite is always present, and usually hornblende in small amount as well. Biotite sometimes occurs instead of hornblende or together with it. The coarser gneisses often show traces of cataclastic structure, larger individuals, usually of feldspar, being surrounded by a granular mosaic which seems to have resulted, at least in part, from the crushing of the larger individuals. The fine grained varieties have the character of this mosaic throughout, the larger individuals being absent, so that, though they are likely akin to the coarser rocks, being simply more thoroughly granulated representatives, due perhaps to original finer grain, it is impossible to be certain that this is the case.

Along with these red gneisses, often interbanded with them with seeming regularity, often found in large masses, are two other kinds of gneiss of common occurrence. Like the red gneiss, they show many variations in composition and appearance, and also show a rude foliation, usually parallel to the banding. The more abundant sort is usually gray in color and consists essentially of pyroxene and feldspar, both plagioclase and orthoclase. The pyroxene may be either augite or hypersthene (or enstatite), or both, augite being the more frequent. The usual augite is a deep emerald green and shows pleochroism from green to yellow green, resembling aegirine augite. Magnetite is always present and sometimes a little hornblende and biotite as well. Either orthoclase or plagioclase may be in excess and either may be present to the exclusion of the other. The plagioclase is usually oligoclase but sometimes andesin. These rocks usually show an evenly granulated or granulitic structure quite like that of the fine grained red gneisses, but how much this is due to granulation, or to recrystallization, or may even be original, can not be determined.

Plate 1



Contact of gneiss and granite near Duane

The other gneisses are black and consist essentially of feldspar and hornblende, with or without pyroxene, in other words, they are amphibolites. They have often a massive appearance and are in general more abundant where the gray gneisses are scarce or absent. The feldspar may be plagioclase or orthoclase or both, but the former much predominates, and is usually andesin or oligoclase. Pyroxene seldom equals the hornblende in quantity and is often absent. The rocks seldom show any traces of crushing but seem to have largely recrystallized.

These rocks often occur in thick bands or masses, often in thinner masses interbanded with red gneiss, and very similar rocks are often found in thin bands or bunches in the red gneiss. The latter may be either segregations or inclusions, it being usually impossible to determine which. Very similar rocks are also found as dikes cutting the red gneiss. These usually have a more rusty appearance than the ordinary rock and may be either offshoots from it or may represent a different and later rock.

These amphibolites are often found involved with red, granitic gneisses which cut them intrusively, both cutting across the foliation and sending a multitude of thin sheets into the amphibolite along the foliation planes, producing a red and black gneiss [pl. 1]. In such case the amphibolite is clearly the older, but in all such the question arises whether the granite is merely a phase of the ordinary red gneiss, or whether it is a different and younger rock. Since in nearly all cases these granites are not so foliated as the red gneiss, but retain distinct traces of igneous textures, often abundantly, it is thought that they are likely younger and not to be classed with it. Among other localities such granites are widely shown around St Regis Falls in Franklin county.

Nearly all, if not all, of these doubtful gneisses seem to have the composition of igneous rocks, though the question can not be fully decided without a large amount of chemical work. The gray gneisses are perhaps the most questionable in this respect. There

is a range in composition from granites through syenites and diorites to gabbros, all intermediate gradations appearing. If there be any rocks exposed in the region which are older than the Grenville rocks, they are found here. Unmixed with Grenville rocks, they extend along the Potsdam boundary on the north side of the Adirondacks for a distance of 70 miles. Nowhere else in the region is a belt of such length known, though there may prove to be one of even greater dimensions in the little studied southwestern area. Smyth has shown that a great, unbroken extent of gneisses occurs there, but these may prove in large part to belong with the later intrusions. Grenville gneisses may be also found more abundantly than yet appears, when the region is covered in more detail. Such gneisses are abundant north from Little Falls, though no limestones occur.

These gneisses present just such an igneous complex as is found in all parts of the earth's surface where these very old rocks are exposed, which are thought by many to represent the original cooled crust of the earth, or rather its downward extension. There is much to be said in favor of this view, though it can by no means be held to be fully established. The main difficulty of its adoption so far as these special rocks are concerned is that very similar, or identical, gneisses are found either interbanded with the Grenville rocks or else cutting them intrusively, as has already been noted. If the two are not identical, it should be possible to demonstrate differences between them, and the future may show this possibility. If they are identical, the only possible way in which they could represent the floor on which the Grenville rocks were laid down would be to hold that in many places, after the deposition of the Grenville rocks, these underlying rocks had been rendered plastic by heat and compression and had thus comported themselves as igneous rocks. The difficulties against this view are great, and the whole question is a most perplexing one.

To the northward in Canada there are great stretches of country occupied by similar rocks, and the name " Ottawa gneiss " is there given to the formation. Uncertainty as to the equivalency of the

two led the writer, some years since, to propose the name "Dannemora formation," from Dannemora mountain in Clinton county for these gneisses of the northern Adirondacks, the name to serve unless equivalency with the Ottawa gneiss can be shown, in which case that name should be adopted. Since, however, possible confusion with a noted Scandinavian locality may result, the name Saranac formation is suggested to replace it. The rocks are well exposed along the river of that name, in Clinton county, and in its near vicinity.

Anorthosite. This was the first of the somewhat later, great igneous intrusions which invaded the rocks already described from below, breaking them up, pushing them aside or raising them on its back, and inclosing great horses of them in many places. The fact that it has not been so excessively metamorphosed as the previous rocks is indicative that it is considerably younger than they, as is the further fact that its character indicates that it solidified at considerable depth, and that therefore the Grenville sediments must have become buried under a considerable thickness of later deposits, since worn away, before the intrusion took place.

The Adirondack anorthosite is found principally in one great connected mass, seemingly one single intrusion, though this may not be the case, occupying a great area in Essex and southern Franklin counties, of rudely triangular shape with indented base and blunted apex, the base at the north. The base is some 55 miles across, and the hight of the triangle some 40 miles, the area of country involved being some 1200 square miles at a rude approximation. Occasional small areas of other rocks, in part Grenville or doubtful gneisses, in part later intrusives, are found within it, but, mostly, it extends unbroken throughout. The inclusions, or horses, of various gneisses are most numerous near the borders of the mass, and some great tongues of the outlying rocks project into it. There are also a few outlying masses, mostly of very small size, the Rand hill mass in Clinton county, which has an area of some 4 square miles, being perhaps as large as any. These may represent independent smaller intrusions, but

more likely are simply outliers of the main mass, connected with it not far underground. The present areal distribution of the rock merely gives its extent in the plane in which the present erosion surface cuts it. Since this surface is irregular, we have some slight idea of the thickness of the mass, the higher mountain peaks furnishing vertical sections of over 3000 feet. But the amount which has already been removed by erosion can be but vaguely estimated, and the extent of the mass in depth is wholly problematic. Any estimates of the original bulk of the mass can be nothing but pure conjectures, except that it can safely be said that it was vast.

Mineralogy. These rocks are composed mainly, and sometimes wholly, of basic plagioclase feldspar, usually labradorite but sometimes bytownite or anorthite. They are eruptives of the gabbro family extra rich in feldspar, which forms from 90% to 100% of the whole rock throughout most of its extent. The minerals next in abundance are augite and ilmenite (or titaniferous magnetite), followed by hypersthene. Minute apatites are usually present. In the many differing phases which the rock presents, several other minerals creep in, the more common of which are hornblende, biotite, garnet, microperthite, quartz, oligoclase and a sulfuret, either pyrite, chalcopyrite or pyrrhotite. These are the original minerals of the rock except where they are due to recrystallization consequent on metamorphism. Subsequent alteration has locally produced other minerals, notably zoisite, epidote, chlorite, scapolite and muscovite, and surface decay has formed yet others.

The feldspar is usually labradorite, twinning striations showing plainly on fresh cleavage surfaces. The thin section usually shows it to be full of minute, rodlike inclusions, all with parallel arrangement, of some opaque mineral, likely ilmenite. These are likely responsible for the usual dark blue color of the mineral, and probably for the occasional iridescence, in greenish blue colors, as well. This is by no means so frequent or so well displayed as in the Labrador and Norway anorthosites, but is a common phenomenon in the region.

The other minerals call for no special comment. An augite which is light green in thin section, is next in abundance to the feldspar. Orthorhombic pyroxene is in general not so prominent. It is usually hypersthene but sometimes bronzite. Ilmenite always occurs with these, but in the normal anorthosite all these are in small quantity, constituting ordinarily less than 5% of the rock.

Texture. The original anorthosite must have been extremely coarsely crystalline, and likely coarsely porphyritic. Under metamorphism the rock has been granulated in varying degree, here but little, leaving the rock still very coarsely crystalline, there excessively, producing a finely granular rock, all intermediate gradations between the two being found. In the coarser rocks the large feldspars are often from 2 to 5 inches in length and are universally dark colored, often showing straining and bending as a result of metamorphism. The granular feldspar is lighter colored and in thin section does not show the opaque rods which characterize the other. It has plainly originated from the crushing, in whole or part, of the large feldspars, crushing under such great load of overlying materials as to cause the rock to remain firm and resistant during the entire process; in fact, the granulated rock is often stronger than the other.[1]

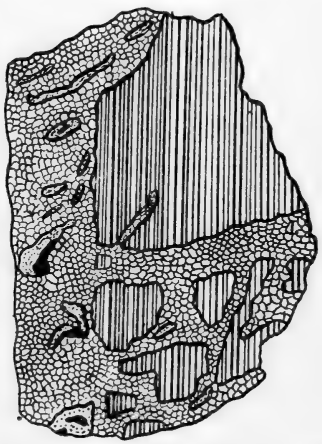


Fig. 1 Drawing of a portion of a hand specimen of anorthosite gabbro from near Keeseville, showing a large labradorite crystal which has been broken into several pieces, these being forced apart and granulated around their edges and the gaps filled by granulated material, the rock remaining firm and tough throughout. The black mineral is ilmenite, and the dotted is granular garnet. The uniform cleavage and twinning of the fragments of the large crystal demonstrate their identity.

Differentiation. As the borders of the anorthosite are approached, the rock invariably shows some variation in character,

[1] For detailed descriptions of these textures, *see* Adams, F. D. Geol. Sur. Can. An. Rep't. v.8. pt J. p.103–15.

the usual one being that the pyroxenes and ilmenite increase in amount and come to constitute from 15% to 35% of the rock, which thus tends to approach gabbro in character. It is, however, much too feldspathic for normal gabbro and may well be called anorthosite gabbro, since it represents a distinct intermediate stage. With this mineralogic change there is always found an accompanying change in texture, the rock becoming always less coarsely crystalline, the big feldspars diminishing in both number and size and the amount of granular mosaic increasing. The rock also becomes more gneissoid. In this phase garnet is sure to creep in, often in considerable quantity. It develops in the main at the contacts between ilmenite and feldspar, the one furnishing the iron, and the other the lime, alumina and silica which enter into its formation. Garnets may form in this way, either during the original cooling of the rock or owing to subsequent metamorphism, and it is usually impossible to say, in these anorthosites, whether they are to be referred to the one or the other, or to both methods of formation.

It is not meant to imply that changes of this sort occur only as the edge of the mass is neared, but rather to point out that they do uniformly occur under those conditions. But the same rock is often produced well within the anorthosite mass by local differentiation. It is in fact but a more extreme differentiation of the same sort that gives rise to the local development of great masses of titaniferous magnetite such as occur about Lake Sanford in Essex county and have been described in detail by Kemp.[1]

This anorthosite gabbro forms the greater part of the boundary of the Franklin county portion of the anorthosite mass. But on the south a yet greater change takes place, and the anorthosite gabbro passes over into a dark colored gabbro gneiss. This rock has not yet been seen in fresh condition, and hence has not received the thorough investigation that its interest and importance demand. The change is of the same sort as that involved in the passage of anorthosite into anorthosite gabbro, but is more ex-

[1] U. S. Geol. Sur. 19th An. Rep't, pt 3, p.383–422.

treme. As has been seen, that consists (1) in a change in composition due to increasing amount of pyroxenes and ilmenite with corresponding diminution of feldspar and the appearance of garnet in quantity; (2) in a change in texture, the rock becoming less coarsely crystalline and the large feldspars diminishing in frequency and size, with increase in the amount of granulated material; and (3) in the rock becoming more prominently foliated with concentration of the dark minerals along the cleavage planes. In this further change the dark minerals come to form 50% or more of the rock; the large feldspars become constantly smaller and less frequent up to complete disappearance; and the rock becomes eventually a finely granular, well foliated, dark gneiss. The change from the anorthosite into this rock is gradual, and the relationship unmistakable; yet to an observer first coming on the rock from without the anorthosite area, such a relationship would seem most improbable. This gneiss is just as clearly a border differentiation product of the anorthosite gabbro as that is of the anorthosite, a differentiation produced in the molten mass after it had reached its present resting place and while cooling. It is however impossible to say why this further differentiation has taken place only on this one side of the mass instead of rather uniformly about the whole, as is the case with the anorthosite gabbro.

Surrounding rocks. The Franklin county anorthosite is bordered by all sorts of rocks, both Grenville and doubtful gneisses and later igneous rocks. That it is younger than the Grenville and some of the doubtful gneisses is definitely established by (1) the fact that masses of varying size are found inclosed in the anorthosite; (2) by the fact that the few contacts exposed show the anorthosite cutting them and sending tongues into them; and (3) by the fact that, where no contacts are exposed, the anorthosite can be shown to cut out the other rocks along their strike. The later date of certain igneous rocks, shortly to be described, is mainly deduced from the finding of dikes of what are thought to be identical rocks which cut the anorthosite. So far as the actual dikes are concerned, there can be no question of their later

date; the uncertainty connected with the matter arises from the fact that in no case has it so far been possible to trace these dikes to any connection with the near-by larger masses, of which they are thought to represent offshoots, so that the correlation between the two depends merely on rock similarity. At the one or two exposed contacts it seems quite certain that the anorthosite is the older rock, but here again there is some question as to the actual identity of the rock which cuts it.

At two localities near the anorthosite boundary, border rocks have been discovered which, instead of exhibiting the ordinary change to anorthosite gabbro, disclose a gradation toward syenite. Such have only been noted in localities where the anorthosite is bordered by a syenite which is thought to be younger, and the rock represents a transition stage between the two, though much closer to anorthosite than to syenite. The precise significance of these rocks is not known, the field exposures not being sufficient to give any idea of the relationships to the two rocks, and, since the presence of an intermediate rock of this sort can be accounted for in several ways, and gives no evidence as to the relative age of the other rocks, speculation on the subject is of no value, in the lack of corroborative field evidence.

Anorthosite outliers. In the northern Adirondacks there are two considerable anorthosite outliers in Clinton county and two very small ones in Franklin county. Not unlikely other small ones will be discovered when the region is mapped in detail, work of this sort on the Long Lake sheet of the new topographic maps during the past season having first brought to light the two Franklin county outliers mentioned above. Kemp has mapped several on the south in Essex and Warren counties.

The two Clinton county outliers are those at Keeseville and Rand hill. The former is not strictly an outlier but rather a tonguelike offshoot from the main mass, the connection being bared by erosion. As in all the outliers, the rock here exhibits the characters of the border portions of the main mass rather than of its center, in other words is anorthosite gabbro, not so coarse grained as, but more gneissoid than the usual rock, with from

10% to 25% of minerals other than feldspar. Much of it is very gneissoid and finely granular, with great development of garnet. Elsewhere it becomes tolerably coarse with frequent, often very large feldspars remaining. It varies very rapidly in character from place to place, so that practically all varieties of the rock may be collected within a small area. This, together with the accessibility of the locality and the frequent exposures, make it a magnificent collecting ground.

The Rand hill rock departs somewhat from the ordinary type and is a most interesting rock. It is mostly thoroughly gneissoid and with no feldspar augen, these only appearing in quantity at the northern edge of the exposures. Since this is the more likely condition of the central part of the mass, and since further exposures in this direction are cut off by the overlying Potsdam sandstone, it is probable that the rock extends considerably farther northward under the Potsdam covering.

The most important difference between this rock and the usual anorthosite gabbro consists in the constant presence of quartz in considerable amount, forming from 5% to 10% of the rock. Another difference is found in the comparatively large amount of apatite present, the average of the rock holding from 3% to 5% of this mineral and the amount not infrequently rising to 10%. Aside from these the minerals are those of the usual anorthosite gabbro, though the minerals other than labradorite form from 30% to 35% of the rock.

The primary minerals which have been noted in the rock are feldspar (usually labradorite), augite, quartz, hornblende, hypersthene, apatite, ilmenite, zircon, pyrite, pyrrhotite and titanite. Secondary minerals are garnet, hornblende, biotite and quartz. There are other minerals present which have resulted from surface alteration of the foregoing, but they are the usual decomposition products formed under such circumstances. The order of crystallization was the usual one, first the zircon and apatite followed by the iron ores, then the hypersthene, augite and hornblende, then the feldspar and finally the quartz. The periods of formation of the pyroxenes and feldspar largely overlap. Augite is

much more abundant than hypersthene. There is great variation in the relative amounts of augite and primary hornblende, and sometimes the latter preponderates.[1]

The two outliers in Franklin county are very small, each only a few square rods in extent. The one is about 6, the other some 8 miles distant from the edge of the main mass. Considering their small size, they are rather surprisingly coarse, that is, on the hypothesis that they were intruded into the surrounding rocks, yet much of the rock is very gneissoid. In the one case the surrounding rocks are thought to be later eruptives, the observed contacts seeming to bear out that view, so that the anorthosite is in the nature of a huge inclusion in these eruptives. But there are some difficulties in the way of this interpretation, and, till the material is more thoroughly studied, it can not be positively stated that it is the true one.

About the other outlier there are no exposed contacts with the surrounding rocks, which are gneisses of uncertain nature and origin, and the relations between the two are wholly uncertain.

At Rand hill magnificent contacts of the anorthosite gabbro with gneisses thought to belong to the Dannemora formation, are shown and definitely prove the anorthosite to be the younger rock.

Whiteface type of anorthosite. This name has been proposed by Professor Kemp for a peculiar type of rock, rather uncommon in the Adirondack region, which reaches a considerable development on, and in the vicinity of, Mt Whiteface. The main mass of the rock is in Essex county, but it gets over the border into Franklin at Franklin Falls, and into Clinton county on Wilmington and Catamount mountains. In both of these situations it becomes much involved with other rocks, and about Franklin Falls it often appears so interbanded with Grenville rocks as to seem like an integral part of the series.

The rock has the mineralogy of anorthosite, or rather of anorthosite gabbro, though quite a different-looking rock from the ordinary types. It is mostly quite thoroughly gneissoid and characterized by the color of the feldspar, which is milky white, even when perfectly fresh and unaltered. In the writer's exper-

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[1]For a more detailed description of this rock, *see* 19th An. Rep't N. Y. State Geol. p.r52–r59.

ience with the ordinary Adirondack anorthosites, white feldspar is rare and where occurring is due to local alteration, which is distinctly not the case in these "Whiteface" rocks. These are also much richer in hornblende and pyroxene than the ordinary anorthosites, though nearly pure feldspathic types have some small local development, as for example near the bridge at Franklin Falls. They differ also in the prevailing very gneissoid character, but occasional feldspar augen do occur and sometimes reach considerable number and size. A single hand specimen of the feldspathic rock from Franklin Falls which lies before me, shows three such augen which are more than an inch in length, besides several smaller ones. The structure is plainly cataclastic in these less gneissoid types.

The slides from the Clinton and Franklin county rocks show a general predominance of hornblende over pyroxene, though both occur in considerable amount. The pyroxene is a deep green augite, no hypersthene having been noted. The feldspar is mostly labradorite, as indicated by maximum extinctions of from 22° to 27° in the different slides. They show marked strain phenomena, such as undulatory extinction, bent twinning lamellae, and wedge-shaped or pinched out twinning lamellae. There is always some untwinned feldspar present, which is however thought to be labradorite. The accompanying minerals are the same as in the usual anorthosite, iron ores, zircon, apatite, titanite, garnet, and sometimes a little quartz, usually as a by-product of the garnet formation. The mineralogy of the rock, the local cataclastic structure, and the fact that it occurs in a considerable mass, surrounded on all sides by other rocks, seem to point to its igneous nature. The apparent interbanding with Grenville rocks at the edge of the mass gives that portion a sedimentary look, but all the other igneous rocks of the district show similar phenomena at their borders, and it would seem that the clues to the origin of these rocks must be sought in the least changed, most massive portions, rather than in their peripheral phases where metamorphism has been most excessive. The rock is therefore regarded as igneous and as belonging to the later intrusives. Its localized distribution would seem to indicate that it represents a separate intrusion rather

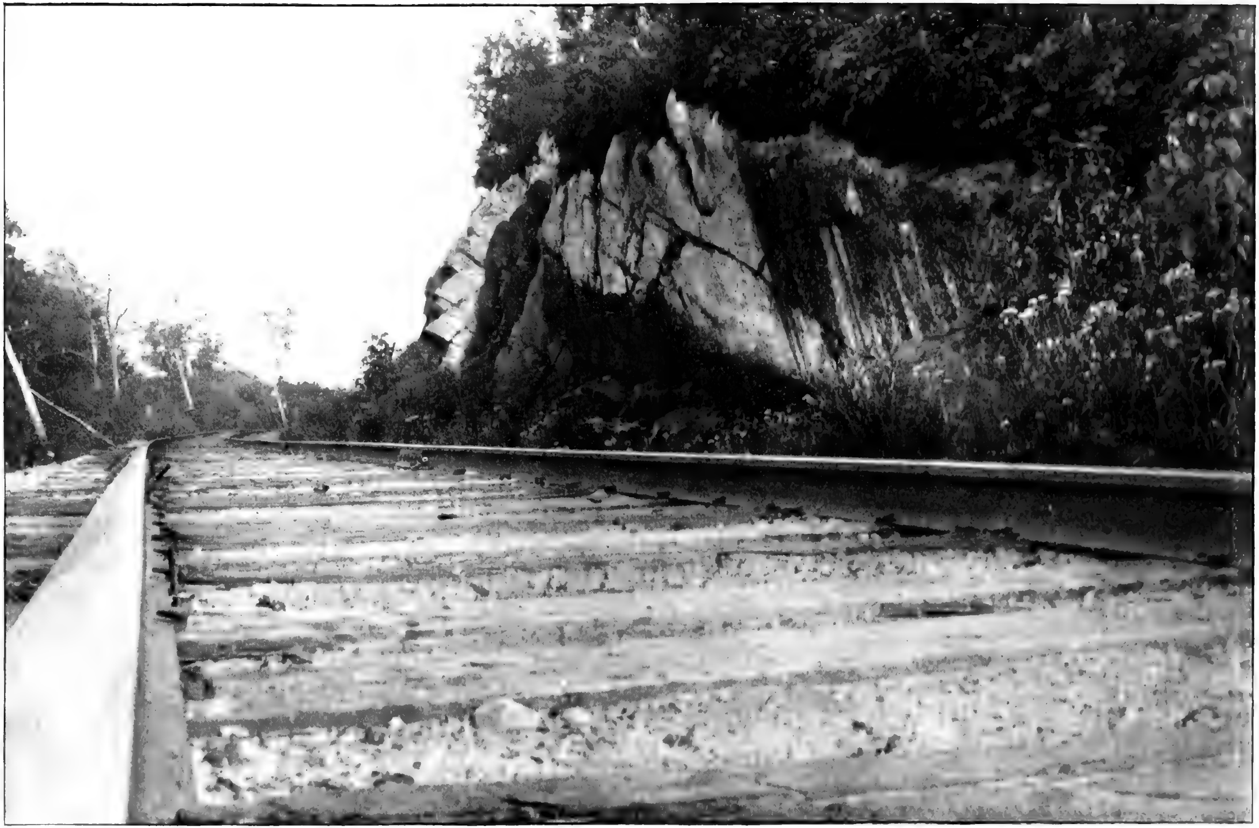
than a local peculiar phase of the general anorthosite mass, but, so far as the writer is aware, no definite evidence has been forthcoming concerning the time relations of the two rocks.

The syenites. In many parts of the Adirondack region there are found considerable areas of igneous rocks of greenish gray color and fairly uniform character, which have considerable resemblance to some phases of the anorthosite and were till comparatively recently confounded with them. In their normal phases they are readily recognized, but they show variation both in composition and in degree of foliation, giving rise to varieties from one or both of these causes which are difficult of recognition. Originally they possessed nothing like the coarsely crystalline character of the anorthosites and hence, even where least metamorphosed, the amount of granulated material is very large, and the uncrushed feldspar remnants are infrequent and of small size. Like the anorthosite, they become finer grained and more gneissoid near their borders, passing over into granular gneisses; and these become intricately involved with the bordering rocks, the whole forming a tangled complex which is exceedingly difficult to unravel.

Though grayish green on freshly fractured surfaces, these rocks undergo rapid color changes on exposure, so that the normal color is only to be seen in recent rock cuts. On slight exposure it changes to a more pronounced green, then passes over to a yellowish or brownish green, and longer exposure changes the whole mass to a rusty brown [pl. 2]. Even freshly stripped, glaciated surfaces show the latter color, though in them it is often only skin deep. In the majority of exposures only the rusty brown rock can be collected, though residual green spots may often be noted. The cause of the color changes is not manifest, thin sections of specimens of all the varieties except the rusty brown showing all the constituent minerals in perfectly fresh condition; and even the latter is often so fresh as to show little alteration in any of the minerals except the hypersthene.

These rocks are predominantly feldspathic though not so markedly so as are the anorthosites. Because of their original finer grain, they are mostly quite gneissoid, and feldspar augen

Plate 2



Railroad cut in augite-syenite ½ mile south of Loon Lake depot. The dark portion is fresh and of green color; the lighter portion is somewhat weathered and is brown

are practically absent over considerable areas, and, where they do occur, are mostly few and small. Yet such rocks are repeatedly found shading locally into others with much less apparent gneissoid structure, with feldspar augen quite frequent and with definite cataclastic structure; rocks whose original igneous textures are sufficiently well preserved to show their origin beyond a doubt.

In some cases, notably at Little Falls and Middleville in Herkimer county, where outliers of these rocks occur and where the augen are bigger and more numerous than at any other known localities, the rock seems to have originally been rather coarsely porphyritic. But for most of the rock in the region this does not seem to have been true.

Mineral composition. At the type locality, Loon lake, the rock is a quartzose augite syenite, and, since this is the prevailing character over much of the region, the description of the type will serve well for a general description of the rock.

In the Loon lake rock microperthite and oligoclase feldspars, augite and hypersthene (or bronzite), hornblende, magnetite, quartz, garnet, apatite and zircon are always present, and locally biotite, titanite, pyrite and allanite appear in addition. The rock is essentially composed of microperthite, augite and hypersthene, with quartz, oligoclase and garnet always present in varying and usually slight amount.

The feldspar is mostly microperthite. A little plagioclase always appears and seems universally to be oligoclase. Most of the plagioclase present is intergrown with orthoclase in the microperthite, and the chemical analysis indicates that this must be albite. The feldspar is usually perfectly fresh and contains to some extent minute, dustlike inclusions, as well as including small zircons, apatites and titanites and occasionally small augites and quartzes also. Orthoclase is only present as a constituent of the microperthite.

Both augite and hypersthene are usually present, the former mostly predominating. Parallel growths of the two frequently occur, often of repeated fine lamellae, the contact faces being as usual. The augite is deep green in thin section, quite like the green of the hypersthene.

Garnet occurs only sporadically and then always corrosion zone fashion, between the magnetite and feldspar. But little hornblende is found in the Loon lake rock.

In the type rock quartz occurs only sparingly, though quite quartzose varieties occur in the immediate vicinity. It is mainly in rather coarse, elongated spindles or lenses. It is also found as small inclusions in the feldspar, sometimes rather numerously and with a tendency to the production of micrographic growths.

The rock has a cataclastic structure, ranging from rather coarse varieties to those which are thoroughly gneissoid, and the granulation pretty complete. In other words, it shows the same variations in texture which the anorthosites exhibit, except for the lack of the very coarse varieties.[1]

Variability of the syenite. While this description will answer for the usual rock in many places, it shows great variability. On the one hand, the amount of quartz varies widely, rocks which contain as much as 20% of it being not at all uncommon. Increase in quartz is commonly accompanied by decrease in the amount of pyroxene and hornblende present, and hence by disappearance of well marked foliation, it being replaced by a linear structure due to the spindle form of the quartzes and their parallel alinement. This structure is quite characteristic of some of the igneous rocks of the region. This quartzose variety is usually coarsely granular and seems to weather even more rapidly than the ordinary rock, so that it is very difficult to obtain in fresh condition, and usually only the rusty brown rock can be found. It is the great similarity of this variety, which can be traced into the normal rock through all gradations, to the brown, quartzose gneiss north of Franklin Falls which Kemp regards as a possible Grenville conglomerate and which has already been referred to, that causes the writer's hesitation in accepting that origin for the rock. It may be also added that, whereas this Franklin Falls rock is adjoined by Grenville sediments on one side, it is also adjoined by augite syenite on the other, so that areally the connection with one sort of rock is no closer than with the other.

Another common variation in the rock is brought about by changes in the relative amounts of pyroxene and hornblende. In

[1] For a more detailed description of these rocks, *see* Geol. Soc. Am. Bul. 10:177–82.

the ordinary rocks the pyroxenes much predominate, but these shade into rocks in which the reverse is true, the hornblende increasing up to complete exclusion of the pyroxenes. With this increase in hornblende biotite always appears in the rock, this mineral being usually lacking in the pyroxenic varieties. Further, the more quartzose varieties are more apt to be those with predominating hornblende, though this is by no means a general rule.

Extreme variations. Besides these minor changes in character, more extreme variations of these rocks occur, on the one hand into granitic, on the other into gabbroic rocks, variations which can however be traced into the ordinary rock step by step.

The most striking instance of a change of this sort which has received careful description is found in Smyth's account of the Diana syenite belt.[1] At the time when this paper was written the syenites had not been differentiated from the anorthosites and gabbros, and the rock was described as a variety of gabbro, and its variations as variations of a gabbro mass. Smyth's description, however, shows that he clearly apprehended the differences between the rock and ordinary gabbro, and he distinctly states its syenitic character, and moreover in a later publication wholly withdraws the rock from the gabbro class.[2] Unfortunately this has not been apprehended by the several writers who have had occasion to refer to this important paper, and the special variation into a red gneiss which will be shortly described is referred to as a variation of gabbro into red gneiss. The truth is that no such variation of gabbro is known in the region, while variations of the syenite into red, granitic gneisses are the rule rather than the exception.

The special interest attaching to this Diana syenite arises from the clearly exhibited differentiation of the gray, feldspathic syenite into a dark colored rock of gabbroic appearance. The minerals are the same in both and are practically the same as in the Loon lake rock, but the pyroxene and hornblende are in much larger quantity in the dark rock, constituting from one third to one half of the whole, while they appear in but scant amount in the ordinary syenite at Diana. At the same time plagioclase increases in amount at the expense of the microperthite, and

[1] Geol. Soc. Am. Bul. 6:271–83.
[2] N. Y. State Geol. 17th An. Rep't. p.472.

quartz diminishes, but it does not disappear, and the plagioclase remains acid, albite to oligoclase, instead of the labradorite of the gabbros. The affiliations of the rock therefore remain with the syenite, and it does not become a true gabbro. Chemical investigation brings out the same features, as will be later shown.

Of equal interest is the passage of this syenite into a red gneiss. In one direction the passage is into a finely granular red gneiss, which Smyth states to differ from the main rock only in a more complete granulation of the constituents, the formation of a little hematite, which causes the color change to red, and an increase in the amount of quartz. In another direction the transition is into a coarser red gneiss which contains a conspicuous amount of hornblende.

Besides these important evidences of great variation in the syenite mass, the Diana area is noteworthy in yet another respect. It borders a long belt of Grenville rocks for several miles; and Smyth has presented in great detail the perfectly clear evidence that it cuts the Grenville rocks intrusively, since it contains abundant inclusions of them, and since it cuts them out along the strike.[1] These relations are here shown in greater perfection than in any other locality so far described in the Adirondack region, and seem to the writer to show not only that the syenite is younger than the Grenville rocks, but also that it is considerably younger. The less severe metamorphism which it has suffered, as evinced by the considerable extent to which it retains original textures which definitely show its igneous character, when compared with the completely crushed and recrystallized condition of the Grenville sediments and associated igneous gneisses, as well as with much of the Saranac gneiss, would seem to demonstrate this clearly, and to show that, so far as age is concerned, their condition of metamorphism would require their classification with the anorthosites, rather than with the Grenville and Dannemora rocks.

Other syenite areas. So far as the Adirondack region has been studied, these syenites seem to be more abundant and important rocks in Franklin county than elsewhere, though it is possible

[1] 17th An. Rep't State Geol. p.474–81.

that future work will show that this is not the case. There are several considerable masses of the rock in this county, the chief ones being the Loon lake, Tupper lake, Saranac river, Duane and Salmon river areas. They all show very similar rocks, and all run into mixed rocks at their boundaries, that is, gneisses which seem referable to the syenite are inextricably involved with other rocks of all sorts, so much so as utterly to defy mapping except on an unwarrantably large scale. The Saranac river mass gets over the border into Essex county, and there are some small masses of the rock in Clinton county, notably in Black Brook township. Kemp has noted the presence of much similar rock in Essex, Warren and Washington counties, though here usually very gneissoid and so much involved with other rocks as to render it somewhat uncertain whether it is of the same age as the Franklin rocks or not. Undoubtedly much of the rock will be found in Hamilton and Herkimer counties when these shall have been more carefully investigated. The work of both Kemp and Smyth in these counties indicates the presence of a considerable quantity of this rock, though mostly in small masses, so that the gneissoid border phases, involved with other gneisses, are the usual types found.

Special reference may be made to the Little Falls syenite in Herkimer. The coarse syenite of the Precambric outliers at Little Falls and Middleville is very similar and wholly uncontaminated with other rocks except for a few cutting dikes. They seem quite certainly parts of the same mass whose extent is concealed by the rocks of the Paleozoic cover. To the northward is a large area of a very gneissoid syenite, much involved with other gneisses mostly of Grenville age, so much so as to defy attempts to fix the relationships of the two, but forming a complex very like that around many of the belts.

A further special interest attaching to the Little Falls syenite arises from its plainly shown gradation into a gabbroic-looking rock which is very similar to the corresponding rock at Diana and represents a variation of precisely the same sort.[1]

In one of the cuts at Loon lake is an apparent inclusion of Grenville rocks in the syenite, which is by no means so decisive

[1] For details *see* N. Y. State Geol. 20th An. Rep't. p.r85–r92.

as to the age relations as are the Diana exposures, but which nevertheless presents some interesting features, as indicated by the accompanying section [fig. 2]. The augite syenite constitutes the center and south end of the section. It is more thoroughly granular and gneissoid than in the neighboring exposures. Separating the two syenite areas is a mass of banded gneiss 12 feet in thickness [pl. 3]. Above is a 2 foot layer of a white, granular rock composed of quartz and white pyroxene in the proportion of 1 to 2. This is followed by layers of black pyroxene granulite and light colored quartzose rocks, the latter consisting essentially of quartz and alkali feldspars in the proportions of 2 to 1. The structure and composition indicate the sedimentary origin, and identical gneisses are found elsewhere in intimate association with limestones. The section is cut at but a small angle with the strike, and but one of the contacts is exposed.

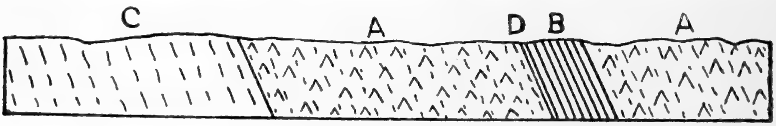


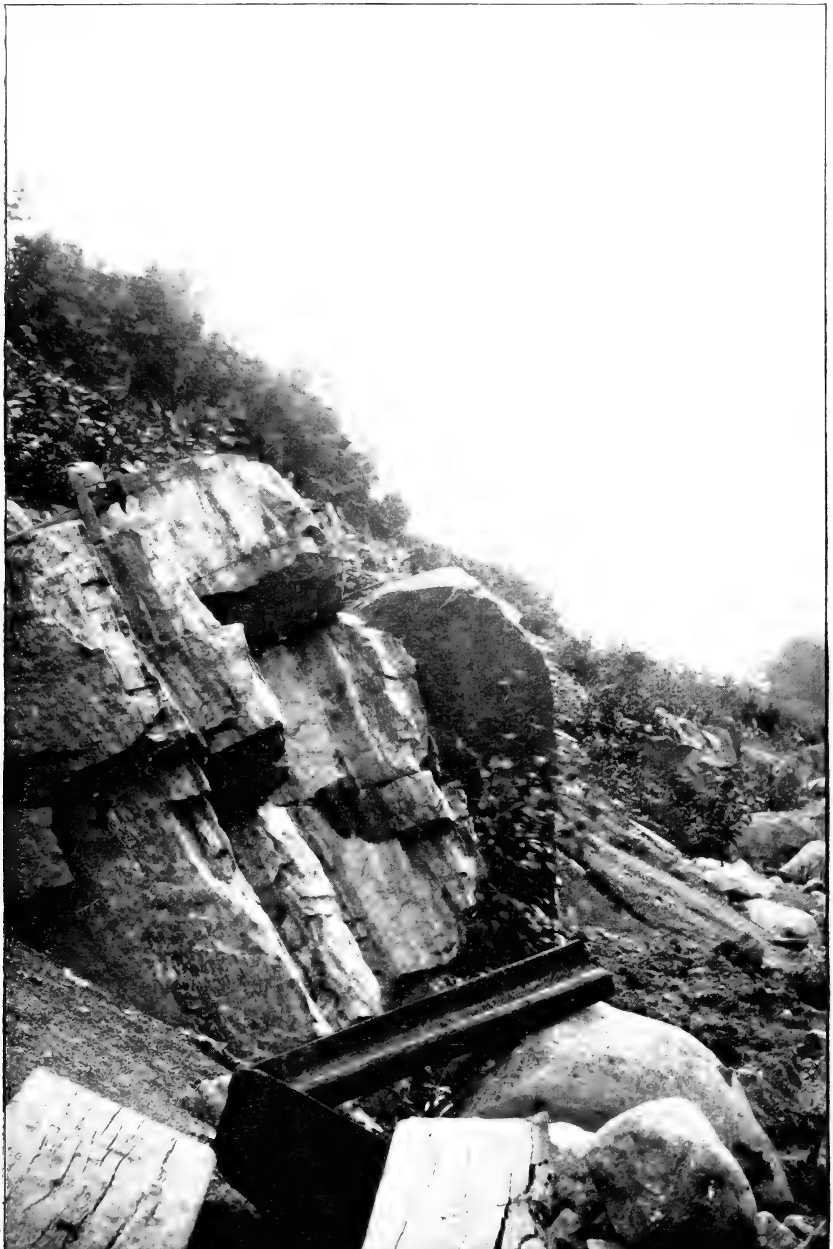
Fig. 2 Section in railroad cut near Loon lake, N. Y. *A*, augite-syenite. *B*, well banded quartzose gneisses. *C*, quartzose gneisses. *D*, biotitic sheared strip—strike north 10 degrees west. Dip of bedding and foliation 65 degrees to the west.

This is parallel to the foliation and bedding and appears like a shear zone, marked by abundant development of biotite. Beyond this middle mass of syenite fine grained, red, granitic gneisses come in, which are likely igneous but quite like rocks often closely associated with the Grenville. The contacts of this rock with the syenite are not exposed. All the rocks have a common foliation, which is also parallel to the banding of the banded gneiss.

While the field relations are not well shown, the fact that the syenite extends unbroken for some distance on all sides of the exposure, and that no Grenville rocks are elsewhere exposed, makes it evident that we are dealing with but a small mass of these rocks wholly surrounded by syenite and hence of the nature of an inclosure in it. Many examples of precisely similar nature may be cited from the areas occupied by the great intrusions.

Relations of syenite and anorthosite. Just as the Diana syenite belt, because of juxtaposition to a considerable area of the Grenville rocks, has furnished conclusive proofs of the age relations

Plate 3



Banded gneiss included in augite-syenite. The hammer is at the contact

of the two, so the evidence of age relations between syenite and anorthosite must be sought from those masses of the syenite which adjoin anorthosite. The only two such masses in the northern Adirondacks, aside from the small anorthosite outlier in Litchfield park, Franklin county, are the Tupper lake and Saranac river syenites. Each of these has furnished some evidence.

A long cut on the Saranac branch of the New York Central and Hudson River Railroad near Colby pond exposes an apparent dike of a gabbroic-looking rock some 30 feet in width, in the midst of the anorthosite gabbro of the cut. The dike shows a heavy blackish rock, darker colored and finer grained than the anorthosite gabbro. The thin section shows that its affiliations are with the syenites, and that it is quite like the gabbroic phase of the Diana syenite. It holds some 35% to 40% of minerals other than feldspar, these being augite, hypersthene, hornblende, biotite, garnet, magnetite and quartz (with small amounts of zircon, apatite, titanite and pyrite). The feldspar is entirely of intergrowth types, fine microperthitic or micrographic intergrowths of orthoclase and albite (or oligoclase). Quartz makes some 5% of the rock. The nature of the feldspar makes reference of the rock to gabbro impossible, yet it looks exceedingly like the ordinary dark gabbros of the region and is very difficult to tell from them in the field.

The west wall of the dike is well shown and is sharp, so that there seems no doubt that it actually is a dike. The igneous nature of the rock is beyond question.

Since the anorthosites grade at times at their borders into gabbroic gneisses which positively can not be distinguished from these gabbroid syenites in the field, it is evident that boundary mapping is attended with considerable hazard in districts where the two rocks adjoin and both show this differentiation.

A similar dike, 8 feet wide, is found cutting anorthosite in a railroad cut 3¼ miles west of Saranac Inn station. The main difference between the two rocks is that in this dike the feldspar, instead of consisting entirely of intergrowth types, as in the previous case, shows quite a considerable percentage of andesin, though the microperthite largely predominates. The rock is by no means so distinctly a syenite as in the previous case, but is rather an intermediate rock.

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Three miles north of the depot at Tupper lake there is a small rock cut in a gabbroic-looking rock, somewhat more feldspathic than the rock of the two dikes, but very similar nevertheless and plainly closely related to them. It contains some 30% of dark minerals, and its feldspar is all of intergrowth types. Its field relations are with the syenite as a border phase, though it is close to the anorthosite boundary, and both its mineralogy and its chemical analysis show it to be a somewhat basic syenite.

In a cut a mile farther north anorthosite gabbro appears which shows rather frequent labradorite augen, but whose granular feldspars are andesin and microperthite in about equal quantity. In other words, the rock is an anorthosite with syenitic tendencies.

About halfway between Tupper Lake village and Wawbeek an interesting glaciated rock surface is shown by the roadside near the town line, exhibiting anorthosite gabbro cut intrusively by syenite, not as a single dike but as an invasion in force, wedging apart and surrounding great horses of the anorthosite. This syenite shows numerous feldspar augen and much more strongly resembles the usual syenite than do the preceding rocks. It is however more basic than the normal rock, having a considerable pyroxene-hornblende-garnet content. Feldspar forms some 75% of the rock however and is nearly all microperthite.

Nearly 1 mile farther east and hence that much farther within the anorthosite mass, is a knoll of gabbroid syenite almost precisely like the Colby pond dike. Its field relations to the surrounding anorthosite are not exhibited, though from analogy it must be a very large dike or else a small boss.

The small anorthosite outlier in Litchfield park has been already referred to. It is all surrounded by syenite gneisses and with good contacts exposed on one side. The rock is much more acid than in the previous exposures and yet is not normal syenite, though it is an igneous rock, a syenite, and identical with what appear as phases of the normal syenite elsewhere. It becomes fine grained at the contact, while the anorthosite shows no change in grain, and seems quite conclusively the younger rock; hence the disposition to regard the anorthosite as an inclusion in the other.

So far as the writer is aware, these are the only observations so far put on record in the Adirondack region which have any bearing on the relative age and relationships of the two rocks, syenite and anorthosite.[1] They definitely show (1) that the anorthosite is cut by a basic syenite, which is therefore younger; (2) that this basic syenite shows considerable variation from place to place and in one exposure bears a strong resemblance to the normal syenite; (3) that at times the normal syenite shows gradation into a gabbroid phase, best shown at Diana and Tupper lake, which is similar to the rock which cuts the anorthosite; and (4) that the anorthosite gabbro itself shows a tendency to the production of a similar rock by local differentiation, that is, a rock richer in pyroxene-hornblende-garnet content than the ordinary anorthosite gabbro, but with oligoclase andesin instead of labradorite for the feldspar and with the development of much microperthite and some quartz in addition; and that at least one dike of a like rock occurs cutting anorthosite. But it has not yet been demonstrated that the syenite found cutting the anorthosite is connected with the main masses, yet such a demonstration is necessary in order to definitely prove the younger age of the latter. It may be argued however that dikes from a syenite mass would draw their material from its peripheral portions, and, if any differentiation had previously taken place, would naturally be more basic than the main mass. The Diana case proves that such differentiation has taken place on a considerable scale; it has also taken place at Tupper lake, and it is thought that plentiful evidence of the same sort would be forthcoming elsewhere, were it not for the general unsatisfactory character of the rock outcrops which prevail in the woods. It is therefore thought that the evidence strongly points to the occurrence of a considerable body of syenite in the region which is younger than the anorthosite. The occurrence of the syenite in a great number of separate masses renders it possible however that there may be some considerable age differences between them. And the fact that in many parts of the region there occur numerous small masses of similar rocks and some larger ones too, which are thoroughly gneissoid and much

[1] For details *see* N. Y. State Geol., 20th An. Rep't. p.r25–r46.

involved with other gneisses, may indicate a greater age for these.

But the great similarity between the rocks of most of the syenite masses seems to point to a close age relationship. The gabbroid phase of the syenite would seem, like the gabbroic borders of the anorthosite, to be due to differentiation after reaching their present situations. The great similarity between the two gabbroid rocks, as well as many mineralogic resemblances between the ordinary anorthosites and syenites, would be accounted for on the supposition that both rocks arose from the differentiation of a common deep seated magma, the anorthosite being erupted first and the syenite following at a somewhat later date. Such phenomena as are presented by the syenitic phase of the anorthosite, here appearing as a local differentiation of the ordinary anorthosite, there occurring in dikes cutting it, would be explained as, the one due to differentiation in place, the other in the magma beneath, with the ascent of a slight amount of material at this stage, following closely on the heels of the main anorthosite intrusion.

Granites. Perhaps the most abundant of all rocks in the Adirondack region are gneissoid granites and granitic gneisses. These are quite certainly of various ages. The granitic gneisses associated with the Grenville rocks as well as those which make up the bulk of the Saranac formation are unquestionably much older than the anorthosite, as shown at contacts and also by their occurrence as inclusions in the anorthosite. On the other hand dikes of granite are not infrequently found cutting the anorthosite, so frequently and over such a wide territory as to argue the existence of considerable bodies of this rock whence the dikes sprang. They are if anything still more frequent in the syenite, in which small granite bosses appear as well. Also localities are not uncommon in which two different granites are found, the one cutting the other. It seems therefore likely that all the granitic rocks of the region may be separated into two great groups, an older and a younger, the former very gneissoid in character and comprising the granitic content of the Grenville and Saranac formations, and the latter much less gneissoid and affiliated in age with the later great intrusions. In the latter

certainly, and in the former probably, there are granites of more than one, perhaps of several different ages. The Grenville and Saranac rocks have been already described. It remains to consider the others. These appear in several forms, some fine and some coarse grained, some almost lacking in dark colored minerals and others comparatively rich in them, some representing well defined types which may be recognized anywhere, while others are more indefinite and variable, and all are much easier to recognize than to describe.

Granitic phase of the syenite. In several localities syenite has been noted passing into a red, granitic gneiss, as first shown by Smyth for the Diana area. In all cases observed the transition is gradual, and there can be no doubt of the unity of the two rocks. The Tupper lake syenite shows changes of the sort most excellently. The color change is gradual and intermediate rocks of mottled green and red appearance are not uncommon. Such are seen to good advantage in Litchfield park, where the numerous rock ledges, often blasted, along the carefully constructed roadways give exceptional advantages for observation. Quartz increases in amount in these rocks while pyroxene commonly disappears, being replaced by hornblende and biotite, usually in respectable amount. No analyses have yet been made of these rocks, and it may be that they do not quite reach a sufficient degree of acidity to justify their being classed as granites, but it seems that in large part they must do so, and they certainly represent as great a departure from the normal syenite type in one direction as the gabbroic variety does in the other. The rock shows the same variations in coarseness and in presence or absence of feldspar augen that the ordinary syenite exhibits. There is also in some varieties the same tendency of the quartz to assume the lens, or spindle form that is seen in the more quartzose syenites.

In going farther south this granitic phase of the syenite gives place to an even more distinctly granitic gneiss, or rather gneissoid granite, in which frequent patchy outcrops of both ordinary syenite and its granitic phase occur, and this rock extends out beyond the limits of the district which the writer has studied. The exposures have not been so situated as to permit of precise

determination of the relations between the two, and the writer is in doubt concerning them. But whether this is the same rock or a different granite, it is so like the other in appearance and in amount of metamorphism, being mostly fairly coarse and with numerous feldspar augen, that there can be little doubt of the close relationship of the two rocks, and it may be safely stated that the two, if distinct, have arisen from the same parent magma and are not far separate in time. It is simply a question whether differentiation has taken place where the rocks now lie or has taken place beneath.

Running northeast from Litchfield park are two big rock ridges, pitching northwardly with gentle slopes, but breaking down in tremendous cliffs on the southwest, which are constituted of a reddish, coarsely gneissoid rock, grading locally into green patches of unmistakable syenite, which the field relations and the thin sections show to be nothing but an extra acid phase of the syenite [pl. 17]. The rock approaches granite but is not as decisively granitic as the previous rocks. It is however another instance of the passage of the syenite into a granitic rock, and the special interest which attaches to it comes from the fact that it is surrounded on all sides by ordinary syenite and hence seems clearly a central, acid differentiation of a syenite mass.

Occasional local reddish gneisses appear in the syenite of somewhat different nature from the foregoing, and in these the color change is not accompanied by much increase in acidity. A case of the sort is met in the section at Little Falls, the rock in question being a syenite full of feldspar augen, which has locally been so mashed and stretched that the augen have become nearly or entirely crushed, the product being a granular red feldspar which has been squeezed out into flat lenses, often tailing out into the rock as thin sheets of considerable extent. In some of these a bit of uncrushed feldspar still remains, and all stages between this extra mashed condition and the ordinary rock can be observed, so that there can be no question of the origin of the granular red feldspar; the origin of the color change is not manifest however, since the augen themselves are by no means red. Furthermore, the red color is confined to this portion of the rock, and the remainder is still of the gray green of the ordinary syenite. It is

a precisely similar red gneiss that is found showing the intrusive contacts against the anorthosite outlier in Litchfield park, and which is regarded as an unquestionable phase of the syenite. The rock here however is not so mashed as at Little Falls, many augen remaining which are only partially granulated. The color change makes it an easy matter to determine just how much granular material has been produced from the crushing of each large feldspar, and the whole forms a very striking and instructive rock.

Amount of differentiation of the syenite. The field evidence, both at Diana and at Tupper lake, seems conclusive that the syenite varies into a quite basic, gabbroic-appearing rock on the one hand and into red, granitic gneisses on the other, showing thus considerably more differentiation in place than the anorthosites exhibit. The writer is also of the opinion that certain magnetite deposits of the region have originated as extra basic segregations from the syenite magma, in strict parallelism with the similar development of the titaniferous magnetite ore bodies of the anorthosite. He has however yet to meet with a case where the evidence for this is decisive, so that there is no intention here to emphasize this view unduly.

It is not yet clear whether the differentiation shown by the syenite is wholly due to changes in the rock mass itself during cooling, after the ordinary manner of such changes in igneous rocks, or whether it is in part due to the incorporation in the igneous mass of material melted away from the inclosing rocks. If the latter process ever takes place on a large scale, we might expect to find it here, in connection with these very large, and very deep seated igneous masses. The general sharp and clear-cut character of the contacts between the intrusives and the various rocks which they cut, as well as the corresponding sharpness of the contacts against the various inclusions of these rocks in the intrusives, does not seem indicative of any incorporation. Nor does the character of the border portion of the intrusive mass vary from place to place, as it successively cuts rocks of different character, as would naturally be expected on this view. Yet it is difficult to bring certain features in harmony with the other view. The usual result of differentiation is to produce a rudely radial

concentric arrangement of the different rock varieties produced, usually with the most acid rock in the center and the most basic in the peripheral portions of the mass; sometimes however the reverse arrangement occurs, the basic rock being the central one. This of course is in the large way, and insignificant local variations, such as are specially characteristic of gabbros, are not in mind. Now both at Tupper lake and at Diana the gradation into granite appears to be a one-sided one, and with no apparent sign of any tendency to concentric arrangement. At Tupper lake the gabbroic phases of the syenite, so far as they have been noted, are all in the vicinity of the anorthosite, while the gradation into granite is apparently confined to the south side of the mass, and other granites appear in force beyond. This is certainly an unusual arrangement, and the cause, though not now manifest, may perhaps be brought out by more detailed work, specially in the unexplored country to the south.

Morris granite. There is one granite in the region which presents very definite characters, is generally found only in small masses, plainly cuts all the rocks heretofore described and hence is likely the latest granite in the region, and to which for convenience of reference and because of its usual easy recognition it seems worth while to give a name. Hence the term "Morris granite" is suggested for it, because of the considerable exposures which occur cutting the augite syenite on the west slopes of Mt Morris, Franklin county.

The rock is peculiar in that it consists almost wholly of alkali feldspar (mostly microperthite) and quartz. There is a trifling amount of hornblende and magnetite usually present, and occasional minute apatites and zircons, but they seldom form more than 5% of the whole. The feldspar is red in color, usually strongly so. The rock presents both coarse and fine grained phases, and it is the former which so characteristically marks the rock. The quartz is concentrated into long spindles or pencils, or else into long flattened lenses, giving the rock a pronounced linear structure; that is, the structure appears gneissoid on fractures parallel to the spindles and not at all gneissoid on fractures at right angles to them, since here the spindles present their rounded cross sections merely. Since the quartz percentage is high, these large

spindles constitute a considerable portion of, and a very characteristic feature of the rock. Though no analyses have been made, the rock is plainly an exceedingly acid one.

The fine grained phase is however the more common one and is not so easy of recognition. It has the same mineral constitution as the coarse, but largely or entirely loses the spindle quartz character. Intermediate grades however occur. In small dikes it becomes a very finely granular, flinty appearing rock, and, where such dikes occur isolated, there may be considerable question as to their proper reference.

The fact that the two are merely phases of the same rock is shown at several localities, typically perhaps on the west shore of Big Tupper lake between Grindstone and Black bays. Here are excellent exposures which show the typical coarse granite cutting augite syenite, with the fine grained type produced as a contact phase, and constituting only a small proportion of the whole mass of the granite. Other exposures show the two in varying proportion, though as a whole the coarse type is less abundant than the fine.

This Morris granite is the only granitic rock among the later intrusives which belongs to this very acid type, and this makes it easy of recognition when it is associated with rocks belonging to this group, since it is the youngest of them all, with the possible exception of some of the gabbros. But gneissoid granites are not infrequently found in the region which cut Grenville or Saranac rocks and with none of the distinctive later intrusives in the vicinity, granites of a very acid type. When these are of the fine grained sort, as is usual, it is impossible to tell whether they are of the age of the Morris granite or are much older, older than any of the later intrusives. Such granites are quite frequent in the region, and have perhaps a specially wide distribution in the vicinity of St Regis Falls. It is quite probable that there is more than one granite of this character in the region.

Gabbros. These are mostly black, basic, heavy rocks, and have a very widespread distribution, perhaps more so than any of the later igneous rocks, but occur mostly in dikes or small masses, very seldom in masses of such size as are common with the other intrusives. The dikes are without exception fine grained black rocks. The central parts of the bosses are much coarser, the

characteristic structures of the rock being here easily made out with the eye.

These rocks show much variation from place to place, due in part to local differentiation during cooling; in part to mutual corrosive effects of adjacent minerals on each other, both during the original cooling of the rock and as a result of subsequent metamorphism; and in large part to varying severity of metamorphism. Where least metamorphosed, a simple original mineral constitution is usually shown, the rock consisting essentially of plagioclase feldspar (usually labradorite), augite and magnetite; to these hypersthene is frequently to be added, and rarely olivine. These primary feldspars and augites invariably hold a multitude of minute inclusions, the augite specially containing them in such numbers that it would often be impossible to make out the color of the mineral were it not for the fact that a narrow outer zone is usually free from them. Nor is the feldspar far behind in this respect. The inclusions in the augite are mainly opaque and consist probably of magnetite or ilmenite. In large part the feldspar inclusions consist of small augites. The structure is rather prominently ophitic in most cases, that is, the feldspar is in long, lath-shaped crystals, separated by and partially embedded in the stout augite crystals.

From the extinction angles shown by the feldspars from various occurrences, it is quite certain that they show a range in composition from andesin to anorthite, with labradorite the prevailing variety. The augite is of a pale, gray-green shade, nearly colorless in thin sections.

In addition to the foregoing, even the least metamorphosed rocks show much granular material, and rocks which consist mainly or wholly of this, with little or no preservation of the original character, are far more common than those of which the reverse is true. This granular material is, to some extent, due to corrosive interaction of the original minerals of the rock. This is most apt to take place between magnetite and feldspar but also occurs between the pyroxenes and feldspar. In general nothing of the sort takes place at pyroxene magnetite contacts. The main new minerals produced by this action are garnet and a peculiar brown hornblende, with some quartz and often biotite accompanying. These are found arranged zonally between the two

reacting minerals and may perhaps have developed during the cooling of the rock, since they are found in the least metamorphosed portions, and since such phenomena are known in other gabbros which have not been metamorphosed. In this manner are formed the well known "corrosion rims" which appear in many gabbros in all parts of the world.

In addition to these minerals there appear others in the granular condition in all rocks in which there is any trace of metamorphism. These are in the main the same as the original minerals of the rock, plagioclase (mostly labradorite), augite, hypersthene, and green hornblende. It seems quite certain that the material for the formation of these has been derived from the original minerals of the rock, and that the process has been one of granulation and recrystallization. The newly formed labradorite and augite are entirely lacking in the multitudinous inclusions which are so characteristic of the original minerals, and in virtue of which even the smallest remaining fragments of them may be detected. The original minerals may often be seen tailing off into granular material, which has evidently formed at their expense. But the grains are not mere shattered fragments of the larger crystals, but consist of a mixture of all the minerals mentioned above.

Additional minerals which are usually or occasionally present are apatite and titanite frequently, pyrite and pyrrhotite occasionally, and sometimes a little green spinel (pleonaste). Scapolite is sometimes present as an alteration product, and in the gneissoid gabbros there is often considerable untwinned feldspar which may be orthoclase.[1]

Some of the more important localities in the northern Adirondacks where these rocks occur are as follows:

In Clinton county at Keeseville, where occasional dikes of the gabbro are found cutting the anorthosite gabbro, showing that they are younger; at Petersburg, where exposures of a very wide

[1]More detailed descriptions of some of these rocks may be found in the following papers:

Kemp, J. F. Am. Jour. Sci. August 1892, p.109–14.
——— Geol. Soc. Am. Bul. 5:213–24.
Smyth, C. H. jr. Am. Jour. Sci. July 1894, p.54–63.
——— Am. Jour. Sci. April 1896, p.273–81.
——— Geol. Soc. Am. Bul. 6:268–83.

dike are found on both sides of the river, showing both the ophitic and the granular types of the rock; a small boss on the northwest shore of Upper Chateaugay lake, which shows ophitic gabbro in the center passing rapidly into an amphibolite gneiss on all sides; and a considerable boss not far from the lower end of Chazy lake. These all show portions only slightly metamorphosed and still retaining ophitic structure. There are many other places in the county where wholly gneissoid rocks of gabbroic make-up occur as dikes and are in all likelihood referable to this same group. In Franklin county there is a considerable boss by the north branch of the Saranac, 2 miles east of Hunters Home, showing a fairly coarse rock with a comparatively unmetamorphosed core; there is another, well shown in cuts along the New York & Ottawa Railroad, 2 miles above St Regis Falls, which shows beautifully the gradual passage from the unchanged core into amphibolite, the latter containing a profusion of enormous garnets; and there is another showing along the west shore at the upper end of Lower Saranac lake, which is quite a large mass and correspondingly coarse, and which must cut the anorthosite, since it is surrounded by that rock on all sides, though no contacts were seen. There are here also numerous smaller masses and dikes which are more completely metamorphosed. Kemp and Smyth have shown the wide distribution of similar rocks in the eastern and western Adirondacks.

To gabbros of this type, with ophitic structure, the name "hyperite" has been applied by Tornebohm.

In many localities metamorphism has produced an amphibolite from these gabbros, instead of the merely granulitic gabbro. In these amphibolite phases there is always considerable pyroxene in addition to the hornblende, but in the field these are absolutely not to be distinguished from the amphibolites associated with the various gneisses, and these too often contain pyroxenes. Where there is an unmetamorphosed core, the origin and relations are evident, otherwise they are wholly obscure. This gradation is beautifully shown at the localities on Upper Chateaugay lake and along the New York & Ottawa Railroad referred to above.

The fact that these gabbros are found in dikes cutting the anorthosites shows conclusively that they are younger. The writer has noted gabbro dikes also cutting the syenite in the Little

Falls outlier, and hence younger. But he has so far met with no instance of gabbro cutting the syenite masses in the north, nor of cutting the distinctly later granites, though many cases are known in which granitic gneisses of uncertain age are cut. This, together with the fact that there is no evidence to show that the syenite at Little Falls is of the same age as that to the north, causes hesitation in regard to the relative ages of the syenite and gabbro there. It is thought to be highly probable however that the gabbro is the youngest rock, and that the order of appearance of the great intrusions was, first anorthosite, followed in order by syenite, granite and gabbro.

Chemical analyses. A sufficient number of chemical analyses of the rocks of the great intrusions have been made to give a very fair idea of their range in composition, and to show their close relationship to one another. To date, analyses of the later granites wholly fail so far as the writer is aware, and hence the more acid members of the group are lacking. But their mineralogy indicates a close relationship to, and gradation into the others through the medium of the acid syenites, and it may be confidently stated that their analyses will fall regularly into the series, and show a regular gradation from the acid syenites through ordinary granite to the very acid Morris granite.

	1	2	3	4	5	6	7
SiO_2	44.77	47.42	51.62	54.47	54.62	54.38	57
Al_2O_3	12.46	17.34	24.45	26.45	26.5	20.53	16.01
Fe_2O_3	4.63	4.91	1.65	1.3	.75	2.78	10.3
FeO	12.99	10.22	5.3	.66	.56	5.5	
MgO	5.34	5.21	1.21	.69	.74	1.99	1.62
CaO	10.2	8.09	9.97	10.8	9.88	5.39	6.2
Na_2O	2.47	3.48	3.49	4.37	4.5	5.2	4.35
K_2O	.95	1.89	1.27	.92	1.23	3.4	3.53
H_2O	.6	1.13	.72	.53	.91	.5	.15
CO_2	.37	......	......	......	......	......	......
TiO_2	5.26	3.6	......	......	......	.09	......
P_2O_5	.28	.06	.01	......	......	.15	......
Cl	......	.21	......	......	......	.03	......
F	......	......	......	......	......	.03	......
S	.26	......	......	......	......	......	......
MnO	.17	.06	.1	......	......	.01	......
BaO	trace	.04	......	......	......	.16	......
Total	100.75	100.01	99.79	100.19	99.7	100.03	99.16
Sp. gr.	3.09		2.798	2.72	2.7	2.7	

	8	9	10	11	12	13	14
SiO_2	59.7	61.01	60.47	63.45	65.65	66.72	68.5
Al_2O_3	19.52	15.36	16.36	18.38	16.84	16.15	14.69
Fe_2O_3	1.16		.8	.42			1.34
		10.75			4.01	3.42	
FeO	5.65		8.76	3.56			3.25
MgO	.78	.78	1.31	.35	.13	.73	.26
CaO	3.36	4.05	2.94	3.06	2.47	2.3	2.2
Na_2O	5.31	3.68	4.65	5.06	5.27	4.36	3.5
Ka_2O	4.14	3.9	4.71	5.15	5.04	5.66	5.9
H_2O	.52	.49	.09	.3	.3	.77	.4
TiO_2	......	......	......	.07	......	......	......
P_2O_5	......	......	......	......	......	......	.03
MnO	.09	.08	.12	trace	......	.07	.1
BaO	......	......	......	.13	......	......	.05
Total	100.23	100.1	100.21	99.73	99.71	100.18	100.22
Sp. gr.	2.674		2.82	2.72			

Molecular ratios

	3	4	6	8	9	11	13	14
SiO_2 ...	.8603	.9078	.9063	.995	1.0168	1.0575	1.112	1.1417
Al_2O_3 ..	.2397	.2593	.2004	.1912	.1506	.1795	.1584	.144
Fe_2O_3 ..	.0103	.0081	.0174	.0072	.0216	.0026	......	.008
FeO ...	.0736	.0092	.0764	.0785	.1014	.0494	.0475	.0451
MgO ..	.0302	.0172	.0497	.0195	.0195	.0087	.0182	.0065
CaO ...	.178	.1929	.0963	.06	.0723	.0523	.0411	.0393
Na_2O ..	.0563	.0705	.0839	.0856	.0594	.0816	.0703	.0565
K_2O ...	.0135	.0097	.0357	.0439	.0414	.0547	.0601	.0626

1 Norite, wall rock of titaniferous magnetite deposit, Lincoln pond, Elizabethtown, Essex co. Description by J. F. Kemp, analysis by W. F. Hillebrand, U. S. Geol. Sur. 1899. 19th An. Rep't, pt 3, p.407.

2 Gabbro (hyperite), dike near Nicholville, Hopkinton, St Lawrence co. Brief mention by H. P. Cushing. 16th An. Rep't N. Y. State Geol. 1899. p.22. E. W. Morley analyst.

3 Anorthosite gabbro, Carnes's quarry, Altona, Clinton co. Description by H. P. Cushing, analysis by E. W. Morley. 19th An. Rep't N. Y. State Geol. 1901. p.r58.

4 Anorthosite, summit of Mt Marcy, Keene, Essex co. A. R. Leeds analyst. N. Y. State Mus. 30th An. Rep't. 1878. p.92.

5 Anorthosite, Keene township, Essex co. (precise locality not given). A. R. Leeds analyst. N. Y. State Mus. 30th An. Rep't. 1878.

6 Anorthosite showing transition to augite syenite, cut by N. Y. C. & H. R. R. R. nearly 5 miles north of Tupper Lake Junction, Altamont, Franklin co. Description by H. P. Cushing, analysis by E. W. Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r68.

7 Gabbro, intermediate between gabbro and augite syenite and occurring as a basic phase of the latter; from Natural Bridge, Diana, Lewis co. Description and analysis by C. H. Smyth jr. Geol. Soc. Am. Bul. 6:274.

8 Augite syenite from the great intrusion into anorthosite, road from Tupper lake to Wawbeek, ½ mile east of Halfway brook, which marks the line between townships 22 and 23, Franklin co. Description by Cushing, analysis by Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r69.

9 Augite syenite, cut by N. Y. C. & H. R. R. R. 3½ miles north of Tupper Lake Junction and 1 mile from the first anorthosite outcrops, the latter being of the transition type, analysis 6; Altamont, Franklin co. Description by Cushing, analysis by Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r69.

10 Gneiss, referred somewhat doubtfully to augite syenite; occurs involved with a later granitic gneiss in the border zone of the augite syenite; from cut by N. Y. C. & H. R. R. R. between Piercefield and Childwold, and 1 mile from the latter; Hopkinton, St Lawrence co. Description by Cushing, analysis by Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r70.

11 Augite syenite, Loon lake, Franklin co., typical. Description by H. P. Cushing, analysis by E. W. Morley. Geol. Soc. Am. Bul. 10:177-92.

12 Augite syenite, near Harrisville, Diana, Lewis co.; the gabbroic rock, analysis 7, is a differentiation phase of this syenite. Description and analysis by C. H. Smyth jr. Geol. Soc. Am. Bul. 6:271-74; and 17th An. Rep't N. Y. State Geol. 1899. p.471–86.

13 Augite syenite, Little Falls, Herkimer co. Description by Cushing, analysis by E. W. Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r69.

14 Quartz augite syenite, from border zone and accompanied by granite, cut by N. Y. & Ottawa R. R. 2½ miles south of Willis pond, Altamont, Franklin co. Description by Cushing, analysis by Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r69.

Discussion. The gabbros are the most basic rocks of the Adirondack eruptive core, except for their own local, iron-rich differentiations, which give rise to the titaniferous magnetite ore deposits. The two analyses, 1 and 2, represent well their general composition and the usual limits of their variation. They are quite ordinary gabbros and show no differences worthy of mention when compared with most rocks of the sort.

Unfortunately, with the exception of analysis 3, no analyses are available of the transition rocks between the gabbros and the anorthosites, such transition rocks occurring at the borders of the main anorthosite bodies as well as in smaller, separate masses, though the general differentiation of the gabbro and anorthosite must be regarded as having taken place below, in the parent magma of both. The smaller anorthosite bodies, such as those near Keeseville and on Rand hill in Clinton county, the latter furnishing the rock whose analyses appear in column 3, are very

markedly gabbroic. The analysis, however, shows a rock which, in its high alumina and rather low iron and magnesia, is much closer to anorthosite than to gabbro. It, nevertheless, represents an intermediate stage in every single constituent. It was chosen for analysis because of its freshness and in spite of the fact that it appeared to be the most anorthositic portion of the Rand hill body and therefore not a fair representative of its general character. The main rock is a more strictly intermediate one, and the same thing is true of the Keeseville rock and of much of the border of the great anorthosite mass of Franklin county.

As close a calculation as can be made of the mineral composition of the anorthosite gabbro of analysis 3, without analysis of the component minerals, indicates some 70% of feldspar, made up of orthoclase 7.5%, albite 29.75% and anorthite 32%. In addition there are 11.75% of garnet, 7% of augite, 4% of hornblende, 2.5% of magnetite and 5% of quartz. The free quartz is specially noteworthy in so basic a rock, is usually to be found in the anorthosite gabbro of the region, and recalls the quartz norites described by Kolderup as associated with anorthosite in the Ekersund-Soggendal district in Norway. For comparative purposes four of his analyses are appended.

	1	2	3	4	5
SiO_2	53.42	52.61	52.21	53.28	51.62
Al_2O_3	28.36	27.15	19.24	23.3	24.45
Fe_2O_3	1.8	4.05	10.46	7.55	1.65
FeO					5.3
MgO	.31	1.55	2.36	3.02	1.21
CaO	10.49	9.96	7.28	5.01	9.97
Na_2O	4.82	4.53	3.48	3.9	3.49
K_2O	.84	.78	1.09	1.51	1.27

1 Anorthosite (labradorit), Ogne, Norway. Kolderup analyst. Die Labradorfelse des westlichen Norwegens. Bergens museums aarbog. 1896. p.20.

2 Anorthosite norite (labradoritnorit), Ekersund. Kolderup analyst. p.20.

3 Quartz norite, Soggendal. Kolderup analyst. p.16.

4 Quartz norite, Theingsvaag bei Ekersund. Kolderup analyst. p.16.

5 Anorthosite gabbro, Carnes's quarry, Rand hill.

It is to be noted that Kolderup's quartz norites are more typical for the rock than the one analyzed from the Adirondacks, that approaching anorthosite more closely and being more like his

anorthosite norite in many respects. His quartz norites show 10% or more of quartz as against the 5% of the Rand hill rock. But, as has been stated, the larger part of the Rand hill rock is more quartzose than the specimen analyzed and would in all probability approach his quartz norite very closely.

The chemical differences between the anorthosite gabbro of analysis 3 and the anorthosites of 4 and 5 of the original table are slight, 3 showing diminished silica, alumina and soda, and increased iron and magnesia; they suffice however to cause a drop in the feldspar content from over 90% in the anorthosite to 70% in the anorthosite gabbro. In all these anorthositic rocks part of the potash is in the labradorite, replacing a certain amount of soda. Analyses of this feldspar always show it, and, in calculating the rock analyses, it is necessary to assume that part of the calculated orthoclase goes with the albite to form labradorite, in order to bring about agreement between the computation and the observed optical properties of the feldspar.

The rock analyzed in column 6 has the appearance of an intermediate rock in the hand specimen, the feldspar augen resembling labradorite, and being sometimes iridescent, the granular portion having the look of augite syenite. Cleavage fragments from the augen give extinctions of—5° on 001 and—19° on 010, and hence are close to labradorite, Ab_1 An_1. But the granular feldspar is in part microperthite, and in part an acid plagioclase. The alkali percentage is abnormally high for so basic a rock. The total bases bear a very high ratio to the silica and alumina, and the considerable alteration of the augite to a chloritic aggregate renders attempts at calculation of the mineral percentages hazardous. The rock is approximately composed of orthoclase 20%, albite 44%, anorthite 11%, magnetite 4%, and the remainder of augite and garnet in the ratio of 2 to 1, including a little hornblende, apatite and quartz, the latter only as a by-product of garnet formation. In its high alkali percentage and consequent feldspars, the rock distinctly approaches the syenites, though its silica percentage remains that of the normal anorthosite.

The gabbro of column 7 is a most interesting rock. Its occurrence with, and as a differentiation product of an augite syenite body, of which it must be regarded as a basic phase rather than as a true gabbro, and its intermediate position chemically between

augite syenite and gabbro, are very suggestive. Like the intermediate rock of column 6, it departs most widely from both the syenites and the anorthosites in its magnesia percentage, the general Adirondack intrusives being abnormally low in that oxid. It occupies an intermediate position between syenite and gabbro, rather than between syenite and anorthosite, and as such is nearer syenite than gabbro chemically. Through the kindness of Professor Smyth, the writer is in possession of a slide and specimen of this rock. The analysis gives the iron as all in the ferrous condition, but there is quite a little magnetite in the rock, and a rough calculation indicates its approximate composition to be 21% orthoclase, 36.75% albite, 13.75% anorthite, 3% magnetite and 25% augite and hornblende. The feldspar content is quite like that of the preceding rock, the augen consisting of labradorite and the granular feldspar of microperthite and acid plagioclase.

The remaining seven analyses, no. 10 excepted, are all of unmistakable syenite and gave an excellent representation of its variation. The ferrous iron percentage is mostly high, and the results of some of the analyses tend to throw doubt on the reliability of the entire series of ferrous iron determinations, and hence to greatly complicate attempts to calculate the mineral percentages. The two most clearly abnormal results are those of analyses 9 and 13. In the former case the result of the ferrous iron determination exactly equaled the total iron in the rock, yet the thin section showed considerable magnetite present, and a rough separation by means of heavy solutions and a bar magnet proved the presence of at least 5% of that mineral. In the latter case the total iron present is 3.42%, yet the ferrous iron result exceeded 5%. While only these two were on their face erroneous, others, such as nos. 10 and 11, are quite suspicious. The disturbing cause can not be pyrite, since there is so little of it present that the sulfur percentage does not in general reach .01%. It is difficult to see how carbonaceous matter other than graphite can be present, and in an igneous rock any considerable amount of graphite would be surprising. The cause of the vitiation is as yet undetected.

The only analysis so far made of the augite syenite which occurs cutting the anorthosite, analysis 8, indicates that to be

somewhat more basic than the usual rock, and this seems to be true of all such syenite, so far as can be judged by the thin sections. Garnet is much more abundant than in the usual syenite, and bronzite is lacking. The analysis indicates a rock composed of 24.25% orthoclase, 44.55% albite, 5.6% anorthite, 1.7% magnetite, 5.8% garnet, 14.5% augite and 3% quartz. If the ferrous iron be too high, and this is possible, though the discrepancy can not be great in this case, the magnetite and anorthite percentages would be slightly increased and those of augite and quartz diminished. Except for a slight amount of acid plagioclase, the feldspar is all of the intergrowth types, and cleavage fragments from the crushed rock show the optical characters of anorthoclase, viz a + 9° extinction on M, with an acute bisectrix in the center of the field.

The rock used for the next analysis, 9, is from near the anorthosite boundary. Ferro-magnesian silicates are more prominent than usual, considerable hornblende, augite and garnet being present and some bronzite, altogether constituting some 30% of the rock. The lower alkalis show the diminished feldspar percentage, but a calculation is rendered impossible by failure of the ferrous iron determination. On the basis of 5% of magnetite, as indicated by the separation previously mentioned, the calculation gives a silica residue amounting to 13% of free quartz, which is much too high, there being but little present. The remaining analyses require little comment aside from no. 10. No. 11 is regarded as giving the closest approximation to the mean composition of the rock and is from the Loon lake type locality.

The pyroxenes and hornblende which these rocks contain are precisely like those in the anorthosites, strongly suggesting community of origin. The feldspars are alkali feldspars with closely corresponding soda and potash content. In the general rock garnet is a much less conspicuous feature than in the anorthosites, and is often wholly absent. This is but natural, since the garnet is not primary but has resulted from the interaction of feldspar and magnetite. It is a lime-iron-alumina garnet, and the necessary lime for its formation is lacking in the alkali feldspar of the syenite. A further distinction between the two rocks lies in the abundance of zircon in the syenite. It

by no means rises to the dignity of an essential constituent but is much more abundant and attains a larger size than in the usual igneous rock. The syenites contain quartz almost without exception, and the amount increases toward the acid end of the series, the calculation of the analysis of column 14 showing 14% of that mineral.

Analysis 10 is of a green gneiss which occurs associated with granite and granitic gneiss near Piercefield. Its field relationships to the syenite are not plain, and the doubt about its properly belonging with them is not cleared away by the analysis, which falls slightly out of the series in its magnesia-lime ratio and in its total magnesia. The rocks nearest it in silica percentage, 8 and 9, have this ratio, 1:3 and 1:3.5 respectively, as against 1:1.7 in 10. Its ratio is nearest to that of 13. On the other hand, it can be argued that its general great similarity in composition would seem to ally it closely with the syenites, and that these show a great variation in the magnesia-lime ratio, even though it approaches so near to equality in no other.

General characters of the Adirondack eruptives. The analyses in the preceding table are thought to be sufficiently numerous to furnish a very fair representation of the general characters of the Adirondack eruptives, except for the lack of analyses of the granites. The latter vary greatly, ending with very acid rocks composed almost wholly of quartz and feldspar. It is quite safe to say that they will reach 75% of silica and probably higher, and that, since their feldspar is universally microperthite, the ratio of soda to potash will remain substantially as it is in the syenites.

The gabbros and anorthosites are quite normal representatives of these groups. But in the transition rocks between these and the syenites we find low magnesia, low ratio of lime and magnesia to alkalis, and approximately equal amounts of soda and potash, and these characters continue to the end of the series. The soda-potash ratio is a slowly changing one, the potash being at first below, but eventually overhauling and passing the soda in the more acid rocks. In these respects the syenites, and probably the granites, depart somewhat from the corresponding rocks of the Ekersund-Soggendal area in Norway, which also ac-

company anorthosite and gabbro, and which Kolderup has so exhaustively described. In general the Adirondack syenitic rocks run higher in the alkalis and lower in lime and magnesia than the corresponding Norwegian rocks. These differences are but slight, and the general agreement between the two series is very close, but they point to a slight original difference in the character of the parent magma of the two districts. The appended analyses bring this out clearly.

	1	2	3	4	5	6
SiO_2	57	57.11	63.45	64.35	68.5	70.33
Al_2O_3	16.01	17	18.38	15.46	14.69	15.59
Fe_2O_3	10.3	12.48	.42	7.5	1.34	1.4
FeO			3.56		3.25	1.54
MgO	1.62	1.78	.35	.5	.26	1.3
CaO	6.2	3.99	3.06	3.58	2.2	3.05
Na_2O	4.35	3.96	5.06	3.28	3.5	4.5
K_2O	3.53	2.59	5.15	3.54	5.9	1.29
H_2O	.15	......	.3	......	.4	......
TiO_2	......	1.59	.07	1.63	......	.85
ZrO_2	......	......	......	......	MnO .1	.24
BaO	......	......	.13	......	.05	......
Total	99.16	100.5	99.73	99.84	100.22	100.09

1 Basic syenite from Natural Bridge; 7 of previous table.

2 Monzonite from Fuldland near Farsund. Description and analysis by C. F. Kolderup. Die Labradorfelse des westlichen Norwegens, Bergens museums aarbog. 1896. p.129.

3 Augite syenite from Loon lake; 11 of previous table.

4 Banatite from Dypvik near Farsund. Die Labradorfelse des westlichen Norwegens, p.123.

5 Quartz augite syenite from near Willis pond; 14 of previous table.

6 Adamellite from Farsund. Die Labradorfelse des westlichen Norwegens p.115.

So far as their mineralogy is concerned, the Adirondack rocks would fall without question in the monzonite group. The prevailing feldspar is microperthite in which the plagioclase molecule is constantly in excess of the orthoclase, so that they are strictly plagioclase orthoclase rocks. The table brings out the chemical differences, which would seem mainly due to the fact that the plagioclase in the microperthite is albite in the Adirondack rocks and oligoclase in the Norwegian. Certainly the

Adirondack rocks closely approach the monzonite type. They also closely approach Brögger's akerite type (quartz augite syenite) from near Christiania, and seem to occupy a position intermediate between the two. Smyth's rock from Natural Bridge, column 1 of the above table, would certainly fall within the monzonite group, notwithstanding its high lime percentage; and the rock from north of Tupper lake, column 9 of the original table, belongs also in that group lying on the border land between monzonite and banatite.[1] Because of this, it is perhaps more logical to refer all the Adirondack syenite to that group, though as a somewhat aberrant type.

It would therefore appear that in each district a very similar magma has given rise to a very similar rock series, and, it is likely, through a similar differentiation process. The order of succession of the different types can not be compared, since the Adirondack succession is uncertain in one respect. The syenite followed the anorthosite, and then came the granite, but the position of the gabbro is uncertain. It is certainly later than the anorthosite, and certain gabbroic dikes which have been found cutting the syenite lead to the impression that it is later than that, but there is some question as to the correctness of their reference to the main gabbro of the region. There may have been two periods of gabbro outflow, one earlier and the other later than the syenite.

A few dikes, and a few small eruptive masses, of three or four different types, have been noted which are not referable to any of the great masses apparently. But as yet their relationships are obscure. All are younger than the anorthosite, and all are metamorphosed.

General metamorphosed condition of the intrusives. All these igneous rocks have undergone severe metamorphism, as shown by the partial or complete granulation of the original minerals, the large amount of recrystallization, and the production of

[1] The monzonite group was established by Brögger to contain rocks intermediate between the granite syenite group (orthoclase rocks) on the one hand, and the diorite gabbro group (plagioclase rocks) on the other; hence characterized by both orthoclase and plagioclase. Monzonite has a silica percentage between 50% and 60%, banatite between 60% and 66%, and adamellite over 66%.

foliation in varying degree. In all of them the amount of change varies from place to place. In a rude degree all the intrusive masses show greater metamorphism toward their edges than at their centers, and because of this the large masses are apt to show a larger proportion of slightly metamorphosed rock than the small masses do. All of them also show local variations in this respect. As a general rule the anorthosite is the least metamorphosed of all the intrusives. If it were younger than the others, its condition in this respect would find ready explanation; and, not only that, but its condition furnishes a perfectly valid argument in favor of its younger age. Such evidence as exists that it is the oldest, rather than the youngest of the intrusives, has already been given in detail, and, if this be the case, other evidence must be produced to account for its apparent lesser degree of metamorphism. This evidence is of threefold character and derived from the distribution, the original texture and the composition of the rock. The main anorthosite of the district occurs as a single great intrusive mass, while the other intrusives are found in a number of smaller, disconnected masses, hence, for the reason just outlined, the rude relationship between size of intrusion and thoroughness of metamorphism, the anorthosite should in general be less metamorphosed than the others.

The anorthosite was originally a vastly more coarsely crystalline rock than were any of the other intrusives. The granulation of these rocks begins at the margins of the separate crystals and works inward by degrees, so that the amount of granulation necessary to completely obliterate the original crystals is, other things being equal, dependent on their size, since the smaller they are the more margins there are where the process can be initiated, and the greater the rapidity of destruction.

The anorthosite has also a simpler mineral composition than the other intrusive rocks, since it is mainly or wholly made up of the one mineral, labradorite. Hence there is afforded comparatively little opportunity for the development of new minerals by corrosion, so that recrystallization has not gone on to the extent that it has in the other rocks, and in so far as it has occurred, can mostly only give rise to more labradorite.

With the passage of the rock into anorthosite gabbro, recrystallization always comes much more largely into play, because of the more varied mineral composition, facilitating corrosion and causing more or less foliation. It is thought that there is here a reasonable and likely the true explanation of the *apparent* less metamorphosed condition of the anorthosite.

The Grenville and Saranac rocks are apparently more thoroughly metamorphosed than the later intrusions. They are more uniformly granular, better foliated, much more completely recrystallized and with a usual utter lack of all traces of original textures. These same characters are also found in the inclusions of these rocks which occur in the intrusives and seem to the writer to indicate that they were somewhat metamorphosed, at least, before the time of the intrusions. While no doubt the heat and pressure incident on their intrusion must have exerted considerable effect on the older rocks, the evidence does not point to this as of prime importance in their metamorphism.

But the distinction between the two sets of rocks is in many ways not a sharp one and is difficult to apply. The more thorough foliation and complete recrystallization of the Grenville rocks may be accounted for by the fact that they were originally fine grained sedimentary rocks, and that their metamorphism is not necessarily more extreme than that of the intrusives. But the more metamorphosed character of the igneous Saranac rocks can not thus be accounted for. The whole problem of their age and relationships is one of such uncertainty however that it is somewhat unsafe to emphasize comparisons between them and the intrusives. They are cut in places by small masses of the intrusives and they must occur as inclusions in them. The difficulty of the whole matter arises from the fact that the Saranac rocks are so similar to the more gneissoid phases of the granite, syenite and gabbro masses that it is frequently impossible to tell with which rock one is dealing. Small, later intrusive masses in the Dannemora rocks may be so thoroughly gneissoid as to appear like an integral part of the group. Specially among the granitic Saranac gneisses traces of cataclastic structure are often found, and of igneous textures; yet

one can seldom be sure in such cases that one is not dealing with a later intrusive.

That there are igneous gneisses in the region which are older than the anorthosite is certain, since such rocks are found cut intrusively by it. That these rocks are for the most part thoroughly gneissoid, more so than is true of any of the larger intrusive masses, is also certain. It would therefore seem that they must have been somewhat metamorphosed before the appearance of the intrusives, but that the criterion is not one which can be used in all cases for the purpose of discriminating between the two sets of rocks.

If the intrusion of the great igneous masses had been the prime factor in the metamorphism of the older gneisses, their foliation should show a general parallelism to the boundaries of the intrusions. In general it does not show this, but on the contrary is mostly independent in direction. Adams has described a notable instance in Canada, where the strike of the foliation of the gneiss around the Morin anorthosite rather minutely parallels the boundary on three sides of the mass.[1] But it does not follow it on the fourth side, the anorthosite is also foliated near the boundary, and its foliation everywhere parallels that of the gneiss, and Adams regards it as having been produced in both at the same time, and necessarily subsequent to the intrusion.

No similar case of striking parallelism has been noted in the Adirondacks so far as the writer is aware, and it is also true here that locality for locality, the foliation of the older gneisses and of the intrusions corresponds, indicating that it is due to a common cause, operating after the appearance of all the intrusives, since they all show foliation. It is no doubt true, as urged by Adams, that the contact lines between the two sets of rocks will form lines of weakness, along which there will be a special tendency to stretching, and which may locally influence the direction taken by the foliation, when not overbalanced by other things. But so far as the writer's observation in the Adirondacks goes, parallelism is the exception rather than the rule.

The universal concordance in foliation between the gneisses and the intrusives makes it impossible to say whether the former possessed any previous foliation or not. If so, it was either

[1] Geol. Sur. Can. 8 :13J-15J.

destroyed by the later metamorphism, or else the two pressures came from the same direction, and the later foliation was superimposed on the earlier, this being much the more probable of the two.

It has previously been stated that the character of the metamorphism which these rocks have undergone is indicative that they must have been deeply buried at the time of metamorphism. The igneous rocks specially are rocks of the most massive and resistant sort; yet over a large part of the region their constituent crystals have been broken up into a mass of granular fragments, accompanied by much recrystallization. The rock masses have also been shortened in the direction of greatest pressure and extended in the plane at right angles to this, with the production of foliation in this plane; and all this has taken place under such great load that no permanent cracks could form, all breaks being closed up by welding as soon as formed, so that the rocks have in general not been weakened and have often been made stronger by the process. The depth below the surface at which permanent cracks can not exist is considerable and moreover varies with the nature of the rock concerned, being greatest for strong, massive igneous rocks of this character. Yet during metamorphism these rocks were at that depth. The change in shape has been effected by actual movement of the rock particles, so that the rock must have been sufficiently loaded to be plastic. Large feldspar crystals have been bent through considerable angles without breakage. Quartzes have been drawn out into long lenses and spindles. A multitude of phenomena showing stretching of the rock, accompanied by actual flowage of the material, could be cited, yet the strength of the rock has not been impaired. The rocks have been under a pressure whose amount exceeded their ultimate strength, and under a load sufficient to cause welding up of all cracks. The exact depth of burial necessary to bring about these conditions in rocks of this sort is uncertain, but a depth of 5 miles is probably not more than a mile or two wide of the mark in either direction.

As near as can be judged from the small and scattered Grenville exposures in the heart of the district, their foliation is everywhere parallel to the original bedding. It is also true that, over much of the district, the foliation dips are compara-

tively flat, though no such striking instance has been met with as Adams has described in Canada.[1] The general foliation strike in the Adirondacks is n.e. and s.w., and the usual dip is to the east, though there are many exceptions to both rules. In some districts there is evidence of considerable folding of the bedding and foliation planes but it is seldom sharp, and intricate folding and plication occur seldom, if ever. Van Hise has suggested that the development of foliation parallel to bedding may have been initiated by vertical shortening and horizontal elongation below the level of no strain, or of no lateral stress, and that in subsequent compression and folding the varying strength of the different beds controlled the movement and kept it in the same planes.[2] This is an ingenious and very plausible suggestion, the likelihood of which is emphasized by the many evidences of the deep seated character of the metamorphism. But the uniformity of direction of foliation in both sedimentary and igneous rocks shows that the metamorphism which produced it followed the appearance of the igneous rocks, and that it must have been produced in both at the same time.

Late Precambric igneous rocks. Dikes of two sharply contrasted sorts of rocks are of frequent occurrence in parts of the Adirondack region, cutting all of the rocks so far described. They are of all widths up to over 100 feet, though those wider than 30 or 40 feet are exceptional, and few reach those dimensions. The larger number have an approximate east and west trend and are nearly vertical. The more common dikes are of a black, flinty, basic rock, diabase; the others are more variable, but are usually quite acid, red, porphyritic rocks of syenitic make-up.

They are much more abundant in the northeast than in any other part of the region, being exceedingly numerous in Clinton county and northern Essex, so much so that, if massed together, it would be at once evident that they constitute a very respectably large portion of the whole rock mass. Somewhat less than half of Clinton county has Precambric surface rocks, yet some 130 of these dikes are known in the county and there are doubtless many more. Rand hill, Dannemora mountain and

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[1] *Op. cit.* p.11J-12J.

[2] U. S. Geol. Sur. 16th An. Rep't, pt. 1, p.773.

the shores of Upper Chateaugay lake may be mentioned as localities where they are exceedingly numerous. Followed to the south and west, they rapidly diminish in number and become rare or wholly absent. Thus Kemp reports many from Essex county, mainly in the north, but very few from Washington and Warren. Franklin county is much larger and with a proportionate much greater area of Precambric rocks than Clinton, yet only some forty of these dikes have been discovered there, and these mainly in the eastern portion. Though many more doubtless remain undiscovered, the relative abundance can be calculated, and they are six to eight times as abundant in Clinton as in Franklin. In St Lawrence, Hamilton and Herkimer counties they are practically absent, and the few known are toward the northeast. Smyth reports them in comparative abundance in the Thousand islands region on the west border of the district, and a single large dike of diabase is found in the Little Falls outlier on the far south. So far as the present Adirondack region is concerned, the igneous activity of this time centered in Clinton county, dying out toward the south and west. As to the extension northward and eastward, nothing can be stated, since the Precambric rocks pass under a paleozoic cover in those directions. Diabase dikes are however fairly abundant in Canada in the region beyond this cover.

The centering of the activity in Clinton county becomes the more apparent when the distribution of the two varieties of the dikes is taken into consideration, the red, syenite dikes being practically confined to that county. They are far less numerous and of much more restricted distribution than the diabases. Only 26 dikes of this class have been noted, of which 19 are on Rand hill, where exposures are numerous and detailed work has been done. No doubt there are many others elsewhere, but it seems quite certain that they are practically confined to the county, only one having been noted outside its limits, and that in Franklin not far from the boundary. Even on Rand hill the diabases much outnumber them. The display of dikes there is the most impressive known in the Adirondack region. If any volcanos were built at the time, surely the roots of one gigantic one are here.

As has already been stated, these rocks are found at the present

time only in dikes. We see the channels through which the material ascended, but can not be sure whether any reached the land surface of the time, giving rise to true volcanic action, nor do we anywhere get a glimpse of the underlying reservoirs which supplied the material, since erosion has nowhere cut deeply enough to disclose them. It may well be, therefore, that the mere dikes give little idea of the possible importance of this period of igneous activity. But, if great surface flows occurred, or volcanos were formed, it seems strange that no vestiges of their presence remain, since, as has been stated, the character of the dikes themselves does not indicate any very great amount of erosion of the present surface as compared with that of that time. The most of the erosion since has been expended on the paleozoic cover which subsequently overspread this old land surface.

These dikes apparently owe their existence to the same causes which were responsible for the earlier, great intrusions, and mark the last paroxysm of igneous activity from that source. They are wholly unmetamorphosed and are the only Precambric rocks in the region of which this is true. Moreover, in cooling, the chilling influence of the walls has been very marked, indicating comparatively near surface conditions at the time. The borders of even the largest dikes have cooled so rapidly as to be glassy, though the rock may become quite coarsely crystalline toward the center. Little or no trace of such strong, chilling effect is to be found in the older dikes of the region. Occasionally the dikes are even somewhat amygdaloidal, which is also indicative of cooling at no great depth. These characters point conclusively to a much younger age for these dikes. Their time of appearance was not only subsequent to the great metamorphism of the region, but was near the close of the following long period of Precambric erosion. Before their appearance the rocks which they cut had had the greater part of the overlying load of material which covered them during metamorphism, laboriously pared away by the slow processes of erosion, a depth of erosion being involved which necessarily argues the lapse of a vast interval of time.

These rocks are very similar to those of the igneous outflows which characterized Keweenawan time (supposedly late Pre-

cambric) in the upper Great lakes region, and it is thought that they are of approximately the same age.

In only one case has it been possible to make a relative age determination between the two sets of dikes. Near the summit of Rand hill a 15 inch dike of the syenite porphyry, bearing n.65°e., is cut by a diabase dike of the same width bearing e. and w. In this case the diabase is indisputably the younger. While this does not demonstrate that all the diabase is younger than all the syenite porphyry, it at least points strongly to such a conclusion.

Syenite porphyries. The rocks from the various dikes differ considerably. Nearly all of them show porphyritic feldspars, though with much variation in size and abundance. These are usually red, but become greenish in one dike, and in another are of a red violet hue. Except in one dike this is the only porphyritic mineral, biotite also appearing in this case. The dikes are often of pronounced red color, but some are much darker, gray to black, with often a greenish tinge when slightly altered. The narrower dikes are dense, hard rocks with conchoidal fracture and aphanitic appearance and general red color. The larger ones are equally hard and firm, but coarser grained and less apt to be red.

These rocks are essentially composed of microperthitic feldspar and biotite, with accessory magnetite (or specular hematite), hornblende, quartz, albite, orthoclase, microcline, apatite and titanite, and with secondary chlorite, calcite, muscovite, epidote and hematite. Microperthite and chlorite, the latter from biotite alteration, are the only minerals present in all the dikes. Quartz is present in most of them, in quantity varying with the composition. The ground-mass has in general a well marked flow (trachytic) structure.[1]

They show a surprising range in composition considering their rather constant mineralogy, varying from the acidity of granites to, in the case of one dike, a basicity approaching that of basalt.

Diabases. The numerous dikes of this rock in the Adirondacks exhibit many variations in composition and texture, and on the northern slopes of the north foothills of the region, where glacial erosion was powerful and all weathered rock was swept

[1]For detailed description, *see* Geol. Soc. Am. Bul. 9:239–56.

away, they are often found in beautifully fresh condition. They have not, as yet, received the thorough description which they merit, Kemp's account of them being the most exhaustive which has yet appeared.[1]

The usual diabases consist essentially of a plagioclase feldspar, mostly either andesin or labradorite, augite and magnetite. To these olivin must be added in a very large portion of the dikes, the number of olivin diabases equaling or exceeding that of those without this mineral, so far as the writer's observation goes.

The smaller dikes are, almost without exception, porphyritic, and the same is true of at least the borders of the larger ones, though these frequently become sufficiently coarse grained in their central portions to cause this character to lose its distinctness. As a general proposition, the dikes may be said to be characterized by two generations of one or more of the minerals present, sometimes the feldspar alone, sometimes the augite alone, sometimes both, occurring in this way. The olivin, when present, seems always to belong to the first generation.

Three of the Franklin county dikes are notable in containing an orthorhombic pyroxene, bronzite, in considerable quantity. It is porphyritic in all, and with its coming in, olivin retreats. In two of them, it gives rise to beautiful parallel growths with augite of a certain sort, nearly all the bronzites being bordered by a narrow zone of this mineral, after the usual law of such growths. The augite plainly did not begin to form till the period of bronzite formation had passed, and the crystals furnished nuclei favoring augite growth.

In some 25% of the dikes biotite is present, occurring in frequent small scales in the ground-mass, with a notable tendency to border the magnetite crystals. In such situation it has been sometimes regarded as primary and sometimes as a result of magnetite feldspar corrosion. Kemp looks on it as the former, in the Essex county dikes. The writer has been unable to satisfy himself as to which view is the proper one, in the case of his own dikes, though disposed to the latter view.

That these rocks show a notable range in composition is indicated by the considerable variation in the relative amounts of feldspar and augite, the former being very materially in excess

[1] U. S. Geol. Sur. Bul. 107, p.24-27.

in some of the rocks and the latter predominating in others. The olivin diabases are in general less feldspathic than those in which that mineral is lacking. Much variation in structure is also shown which, to a considerable degree at least, depends on composition. The ophitic structure is the more usual one. In many of the dikes, however, the interspaces between the feldspar laths are filled by clumps of smaller augites, instead of the large augites which solidly fill the interspaces in the typical structure. In the more feldspathic dikes the interference of the different feldspar laths with one another, and their abundance much hinder the development of the normal structure.

In many of the dikes there is a more or less well marked tendency on the part of the feldspar laths to assume a radial grouping around various centers, giving rise to the divergent rayed structure. In some such the augites also tend to a long prismatic, or lath, shape, and these may take on an independent radial grouping also. A tendency on the part of the augites to show their own crystal boundaries is found in many of these rocks, as Kemp has shown, producing a grading toward camptonite.

Chemical analyses and discussion

	1	2	3	4	5	6	7	8	9
SiO_2 ...	43.41	44.51	45.46	46.73	50.89	52.53	63.02	67.16	68.96
Al_2O_3 ...	19.42	19.99	19.94	16.66	15.39	18.31	14.87	14.53	15.25
Fe_2O_3 ..	5.72			3.56		.34	6.53		3.28
		7.22	15.36		5.77			4.17	
FeO ...	6.691			8.45		6.43	none		none
MgO ...	5.98	8.11	2.95	8.12	7.6	1.82	.95	.41	.2
CaO ...	9.11	8.15	8.32	8.03	8.75	3.15	1.12	1.26	.76
Na_2O ...	4.39	5.24	2.12	3.73	5.67	7.26	5.85	5.55	5.45
K_2O	.47	2.6	3.21	1.64	2.72	6.47	5.62	6.1	5.01
H_2O	3	2.93	2.3	2.39	2.46	1.16	1.45	1.1	.91
TiO_2 ...	.35	.....	.....	.03	.....	.....	.....	.....	.....
P_2O_5 ...	.....	.....	.....	.39	.....	1.59	.....	.....	.....
Cl	.....	.....	.....	.18	.....	.4	.....	.....	.....
F	.....	.....	.....	.26	.....	.32	.....	.....	.....
Cr_2O_3 ..	.....	.....	.....	.06	.....	.....	.....	.....	.....
MnO ...	.....	.....	.....	trace	.....	.15	.46	.....	.23
BaO ..	CO_2-2	.....	.....	.04	.....	.....	.....	.....	.....
Total ..	100.54	98.75	99.66	100.2	99.25	99.93	99.87	100.28	100.05
O=Cl & F....................				.14		.22			
				100.06		99.71			

1 Diabase from summit of Mt Marcy, Essex co. Analyst Leeds. N. Y. State Mus. 30th An. Rep't, p.102.

2 Diabase from shore of Upper Chateaugay lake, Clinton co. Analyst Eakle. Am. Geol. July 1893, p.35.

3 Diabase from Palmer hill, Black Brook township, Clinton co. Analyst Kemp. U. S. Geol. Sur. Bul. 107, p.26.

4 Olivin diabase, Bellmont township, Franklin co., dike 13. Analyst Morley. 18th An. Rep't N. Y. State Geol. p.120, and 20th An. Rep't, p.r79. Very fresh, olivin not perceptibly serpentinized.

5 Olivin diabase from shore of Upper Chateaugay lake, Clinton co. Analyst Eakle. *Op. cit.* p.35.

6 Very basic syenite porphyry, Rand hill, Clinton co. Analyst Morley. Geol. Soc. Am. Bul. 9:248.

7 Normal syenite porphyry, Rand hill, Clinton co. Analyst Morley. *Op. cit.* p.248, and 20th An. Rep't N. Y. State Geol. p.r79.

8 Syenite porphyry from shore of Upper Chateaugay lake. Analyst Eakle. *Op. cit.* p.34.

9 Acid syenite porphyry, Rand hill, Clinton co. Analyst Morley. *Op. cit.* p.248 and r79.

The analyses quoted above are all that are known to the writer of these rocks. Many of them are quite old but are valuable for comparative purposes, though not going into the minutiae of modern requirements. The diabases show considerable variation, as would be expected, yet on the whole harmonize well with one another. No. 4 is the only tolerably complete analysis, and at the same time seems to represent about a mean between the extreme types and will hence serve as a fair representative of the average diabase of the district. It consists essentially of labradorite and augite in about equal amounts, with considerable olivin and magnetite and a rather unusual amount of biotite, much of which is clearly primary. Apatite is about the only other mineral. The magnetite is only slightly titaniferous, if at all, since the very small amount of titanium present may likely all be in the biotite. The augite is in two generations, but the feldspar not. The structure is only poorly ophitic.

No. 1 is the rock long ago analyzed by Leeds, the analysis not being accompanied by any description however. Augite is the only mineral specifically stated to be present.

No. 2, according to Eakle, appears to lack olivin, and the augite is almost wholly altered to chlorite and epidote. No. 5, according to the same author, is an ordinary olivin diabase, though he makes no mention of augite, and it is only inferentially supposed to be present. It is noteworthy in being exceptionally acid for

these rocks, though the description does not suffice to bring out the cause for this extra acidity.

No. 3, Kemp's Palmer hill rock, is exceptional for the region in that the feldspar is altered to scapolite, and it falls badly out of the series in several respects, notably in its low magnesia and its excess of potash over soda.

The rocks from which analyses 6, 7 and 9 were made, were selected to represent the mean and the extreme phases of the syenitic dikes. No. 6 is much more basic than any other of these rocks known in the region, a silica determination of the one which seemed to approach it most closely showing 59.2%. From this figure to the 68.96% of no. 9 there is apparently no break in the series.

This basic rock consists essentially of feldspar, a portion of which is microperthite and the remainder albite, biotite, apatite and a little magnetite, these in order constituting 61%, 33%, 4% and .5% of the rock. Except for the absence of quartz these are the same minerals which characterize the other dikes, thus indicating the genetic connection of this rock with the others.

No. 7 consists of feldspar, largely microperthite, chloritized hornblende, magnetite and quartz, with a little apatite and much hematite stain. There is about 10% of hornblende and somewhat less than that amount of quartz in the rock, practically all the remainder being feldspar. Except that in most of the dikes the hornblende is replaced by biotite, this is rather closely the average composition of all.

The rock of column 9 is composed of microperthite, quartz and specular hematite, with exceedingly slight amounts of chlorite and apatite. The feldspar makes a little under 80%, the quartz a little over 17% and the hematite a little over 3% of the rock. The feldspar is very typical microperthite or anorthoclase, composed of orthoclase and albite in the proportion of 2:3.

The likelihood that the material of these dikes was derived from the same magmatic source as that of the earlier great intrusions is strongly suggested by a comparison of analyses.

	1	2	3	4	5	6
SiO_2	47.42	46.73	63.45	63.02	68.5	68.96
Al_2O_3	17.34	16.66	18.38	14.87	14.69	15.25
Fe_2O_3	4.91	3.56	.42	6.53	1.34	3.28
FeO	10.22	8.45	3.56	none	3.25	none

	1	2	3	4	5	6
MgO	5.21	8.12	.35	.95	.26	.2
CaO	8.09	8.03	3.06	1.12	2.2	.76
Na_2O	3.48	3.73	5.06	5.85	3.5	5.45
K_2O	1.89	1.64	5.15	5.62	5.9	5.01
H_2O	1.13	2.39	.3	1.45	.4	.91
TiO_2	3.6	.03	.07	......	......	......
P_2O_5	.06	.39	......	......	.03	......
Cl	.21	.18	......	......	......	......
F	......	.26	......	......	......	......
Cr_2O_3	......	.06	......	......	......	......
MnO	.06	trace	trace	.46	.1	.23
BaO	.04	.04	.13	......	.05	......
Total	100.06	100.2	99.73	99.87	100.22	100.05
O=Cl & F	.05	.14				
	100.01	100.06				

1 Gabbro (hyperite) from near Nicholville, St Lawrence co.; no. 2 of first table of analyses.
2 Diabase, Bellmont township, Franklin co.; no. 4 of second table.
3 Augite syenite, Loon lake, Franklin co.; typical; no. 11 of first table.
4 Normal syenite porphyry, Rand hill, Clinton co.; no. 7 of second table.
5 Quartz augite syenite, near Willis pond, Franklin co.; no. 14 of first table.
6 Quartz syenite porphyry, Rand hill; no. 9 of second table.

A comparison of the first two of the above analyses shows a very close agreement between the gabbro and the diabase in composition, the most striking discrepancy being in the titanium percentage. This difference is perhaps sufficiently pronounced to throw some doubt on the magmatic relationship, since in other respects the analyses might be duplicated from many parts of the earth's surface, both gabbros and diabases of this approximate composition being among the most widespread of igneous rocks. If this high titanium percentage was characteristic of the rocks of the big intrusions, it should appear in the diabases, also if they are congenital. But, so far as the analyses go, they do not indicate a high titanium percentage in the big intrusions except in the basic gabbros, and most of the analyses which have been made of them are from specimens taken from the wall rocks of titaniferous ore bodies, which are segregations from the magma which are extra rich in iron and titanium. It is therefore thought likely that this difficulty in the way of ascribing magmatic relationship is more apparent than real.

The syenite porphyries are somewhat lower in lime and higher in alkali percentage than the corresponding syenites. But the differences are not thought to be sufficiently large to condemn a reference to the same parent magma.

Paleozoic rocks

Potsdam (Cambric) sandstone. Lying uncomformably on the old and much eroded Precambric surface, a great sandstone formation appears, on the north and east and on the eastern half of the southern border of the Adirondack region. This is a water-deposited formation, and, so far at least as its upper portion is concerned, a marine formation. It is thickest on the northeast, thinning out to disappearance both to the south and west. As, furthermore, it appears to be the upper beds which persist, and the lower ones which disappear in these directions, it seems certain that, so far as the immediate region is concerned, the marine invasion came on it from the northeast and extended progressively southward and westward.

In Clinton county, where the formation is thickest, the basal portion is rather sharply differentiated from the rest in character, and this portion has considerable thickness, though how much, and how large a part of the whole thickness it constitutes, is wholly uncertain. The writer was the first to show this, and it has lately been reaffirmed by van Ingen.[1] This portion consists in part of coarse basal conglomerates, in part of poorly indurated sand beds of small durability and in smaller part of thoroughly indurated sandstones. It is nearly everywhere characterized by a considerable feldspar content, in addition to the quartz, and this feldspar is for the most part fresh. Considerable magnetite also appears in places, along with grains of garnet and occasional zircons. The rock has therefore an arkose character in this portion, while above it is prevailingly of pure quartz sand. Red is the predominant color of the base, and there is but little white sandstone in it, while above the latter is the prevailing color. As a general proposition, a feldspar content and a prevalence of red beds go together and are certain signs of the basal portion.

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[1] N. Y. State Mus. Bul. 52, p.543.

Basal conglomerates are a prominent feature in Clinton county wherever the proper horizon is exposed. For the most part these are not extra coarse, the larger pebbles seldom exceeding an inch in diameter. The pebbles are prevailingly or exclusively of quartz, derived from the quartz veins of the Precambrian rocks, and are embedded in a coarse sand matrix in which there is a large feldspar, and considerable magnetite content. Along most of the northern border the general lack of pebbles of the underlying rocks, which are mostly Saranac gneisses, is indicative of quite prolonged wear of the material, so that only the extraresistant pebbles of vein quartz origin were sufficiently durable to persist as pebbles. The undecayed character of the feldspar grains of the sands in these conglomerates indicates that all soil and largely weathered rock had already been removed and carried offshore to be deposited, and that the waves were working on tolerably fresh rock, whose grinding to sand had to be performed by water action alone, unaided by any special weakness due to previous weathering.

In some few localities conglomerates indicative of much less vigorous wave action are found. These contain numerous pebbles of the underlying gneisses, often of large size and showing great variation in size, and quartz pebbles are much less conspicuous or lacking. These seem to be purely local deposits laid down in sheltered hollows in the Precambric floor, whose presence is likely due to uneven depth of weathering of the floor rocks. It is in rocks such as these that the pebbles of diabase and syenite porphyry which demonstrate the Prepotsdam age of these dikes, are found. Such conglomerates are much less resistant rocks than the commoner quartz pebble conglomerates, and present exposures usually show them in much disintegrated condition.

These heavy basal conglomerates are mainly confined to the northern border of the region, extending as far west as eastern St Lawrence county. South of Clinton county, along Lake Champlain, their existence is rather problematic, owing to dearth of exposures of the proper horizon, mainly due to faulting.

An interesting outcrop of basal conglomerate occurs not far west of Keeseville in Clinton county, nestling in an indentation in the eastern edge of the anorthosite gabbro, the actual contact

not showing. It is capped by red, feldspathic sandstones of the ordinary basal type. The conglomerate carries numerous quartz pebbles, up to 2 inches in diameter, along with occasional smaller ones of diabase, and of red orthoclase feldspar, the latter clearly from pegmatite veins. The coarsely granular matrix looks black when fresh, becoming green mottled with blotches of chloritic material on weathering. Along with the quartz in the matrix is much microperthite feldspar, considerable magnetite in streaks, and occasional grains of titanite and microcline, all these grains being surrounded by a greenish, chloritelike cement, whose exact nature is not clear.

This conglomerate represents an intermediate stage between the normal, quartzose conglomerates and the local, disintegration conglomerates of the hollows. It is therefore of interest to note that, while it lies in contact with anorthosite gabbro, with no gneissic outcrops within a mile, it is entirely made up of gneissic debris. This may either argue transportation of the materials for at least this distance, which would imply great strength of wave action; or else that gneiss occurred near at hand along the old shore, became covered up by later Potsdam beds, and has since been faulted out of sight. There is no question about the necessary fault being near at hand, and, so far as the writer knows, no evidence which will enable a decision one way or the other.

Very abundant also in the basal portion of the formation, are beds of rapidly disintegrating, very red, coarse arkose sandstones, made up mainly of quartz and feldspar grains and the whole much permeated with red hematite. They break down rapidly to a red, sandy clay, a characteristic soil which is produced by no other rock in the district, and which often shows the presence of these beds when actual outcrops are lacking. Beds of this sort often occur interbanded with the basal conglomerates, or they may constitute the larger part of the base, conglomerates being scarce or absent, as is the case on Rand hill, where these beds show greater bulk than in any other known locality.

Well indurated, red sandstones, such as those from the type locality at Potsdam, are not infrequent in the basal portion of

the formation and are numerously exposed at various localities on the north border of the Adirondacks in such situation as to indicate clearly their horizon. At Potsdam itself the section is complicated by faulting, and the horizon of the red sandstone there can not be demonstrated, though inferentially it is low in the formation. Along with the red there is much hard, glassy, brown sandstone, also containing fresh feldspars, but lacking the hematite coloration of the red beds. Above, the reds become striped and mottled with white, forming a species of passage beds to the middle division.

Van Ingen is the only observer who has undertaken to differentiate between the middle and upper portions of the Potsdam. He says:

The middle portion of the sandstone is made up of well sorted materials, of finer grain, compactly cemented, and of white, steel gray or yellowish color, with very little or no feldspathic content. The grains of sand are both angular and rounded, with the former predominating. The layers are more regular, though their surfaces are ripple-marked, and in section they are seen to be almost universally cross-bedded. Pebbles are found on the surfaces of some layers of the middle portion, but unlike those of the upper portion they seem to have been of soft mud derived by erosion of contemporaneous sediments, cast on the beach at times of rough water and flattened and squeezed out by the subsequent pressure and consolidation of the superimposed sand deposits.

The upper portion of the formation has frequent beds of irregular laminated sandstone, with partings of greenish arenaceous shale. The shale surfaces are covered with fucoids and worm trails. Pebbles of shale and dolomite, which were hardened before the time of their entombment, are found embedded in the sandstone layers, and their disintegration causes cavities to form in the layers containing them. The dolomite pebbles become more abundant toward the upper horizons. In the upper levels frequent beds are composed of nicely rounded grains of clear quartz with a little cement, that crumble to a sugary powder under the hammer. Rounded grains of quartz of a slightly larger size occasionally cover the upper surface of a layer of finer grained sandstone, and, being without cement, they stand out in relief above the surface with an appearance of having been sprinkled from a pepper pot.[1]

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[1] *Op. cit.* p.543–44.

While these differences are by no means so obvious as those which serve to separate the basal beds from the remainder of the formation, they are sufficiently distinct to enable one to recognize the horizon dealt with in good exposures, provided the extension of van Ingen's work over a larger area shows them to be persistent. The writer's work in the district has been mainly that of hurried areal mapping, and is not therefore of sufficiently detailed character to enable him to express an opinion of any value on this work of van Ingen's, though, so far as it goes, he is disposed to coincide. Precisely the same differences which van Ingen notes have been observed, but the work was not done in sufficient detail to warrant publication. In addition it may be stated that frequent pebbly beds occur throughout the formation, in which the pebbles are almost exclusively of white quartz, with a tendency to concentration on the upper surfaces of layers which are otherwise of pure sand, instead of being disseminated through the layer. Such pebbly horizons seem much more characteristic of the middle division than of the upper.

The thickness of the Potsdam in Clinton county is unknown. The thickest measured section is that in the Ausable chasm, but the section there is complicated by faulting and is by no means complete, all the basal portion being lacking. Walcott's measurement gives 350 feet, and van Ingen's "at least 455 feet" as the thickness here. In the Morrisonville well, with the drill resting at 1250 feet in the Potsdam sandstone, at least 750 feet of the formation had been drilled through, and the bottom samples were of clear, glassy quartz sand, with no trace of the feldspars which characterize the basal portion, indicating that it had not been reached.[1] From this record alone it seems perfectly safe to say that the formation has a thickness considerably in excess of that amount in Clinton county. The writer's estimate, based on the broad belt of outcrop in the northern part of the county, assigns a minimum thickness of at least 1,000 feet to the formation, with a likelihood that it is considerably in excess of that amount.

[1] 19th An. Rep't State Geol. p.r69.

Van Ingen's study of the Saranac river section of the Potsdam, extending along the river for 2 miles above and below Cadyville, leads him to compute the thickness there shown at 1150 feet.[1] The writer agrees with him that there is no evidence of faulting in this section, though he believes that it is terminated by a fault at each end. Certainly one of the biggest faults in the district, the Tracy brook fault, crosses the river somewhere between the lower end of the section and Morrisonville, though apparently with much diminished throw hereabouts. The Potsdam is a most difficult formation on which to get accurate dip measurements, and the writer's notes give the dip as somewhat less than that stated by van Ingen, averaging about 5° instead of between 5° and 10°, as given by him, which would cut down the above thickness by some 300 feet. Whichever result be the more correct, the thickness is impressive, since the basal beds do not show, nor is the summit reached. Basal beds do indeed occur in the near vicinity, showing in frequent outcrop on the higher ground a mile south of Cadyville. These are on the strike of the river exposures and at a higher altitude, yet belong much below them stratigraphically, and the writer is disposed to the conclusion that a fault intervenes between the two, likely a branch from the Tracy brook fault. These beds show considerable thickness, and it is thought highly probable that the thickness of the whole Potsdam is more likely over, rather than under 1500 feet.

The paleontologic and stratigraphic work of Walcott and van Ingen has shown that the upper portion of the formation, through a thickness of some 350 feet, carries a sparse Upper Cambric fauna. With the exception of a few supposed tracks, of uncertain nature, no fossils have so far been found in all the remainder of the formation, and there is therefore an utter lack of paleontologic evidence as to its age, and the possibility that the lower portion may be older than the Upper Cambric must be conceded. But it seems to the writer that, fossil evidence being lacking, the formation as it occurs in New York is not susceptible of subdivision. The basal rocks grade into those of the middle division, as do those into the upper, and there is no marked structural break at any horizon which would warrant the assumption of any great difference in age between base and

[1] *Op. cit.* p.532.

summit, or any marked pause in sedimentation. Prof. N. H. Winchell has long held, and has recently reiterated the view, that the typical Potsdam at Potsdam is much older than the upper, white, less indurated beds, and he classes it in the middle Cambric and correlates it with a portion of the Keweenawan of the upper lake region.[1] As above indicated, the writer's judgment is that any present attempt to divide the formation on the basis of age is premature and has but slender basis of fact, considering the lack of all evidence from fossils.

As has been shown by many observers, the transition from Potsdam to Beekmantown sedimentation is not a sharp one but through a series of passage beds. Near the summit of the former, thin beds of gray dolomite make their appearance, interbanded with the soft, white sandstones which prevail there, increase in frequency till they constitute half the mass of the rock, and finally prevail and cut out the sandstones altogether. The sandstone layers are characteristically Potsdam in appearance, and the dolomites as characteristically Beekmantown. There is no mixing of materials but rather a rapid alternation of two contrasted sets of deposition conditions. Walcott has measured a thickness of 25 feet of such passage beds along the Chateaugay river and 70 feet near Whitehall. In the writer's judgment, the latter is much nearer the usual figure than the former. These beds are exposed at many localities along the northern border of the region, but seldom suitably for measurement of thickness. They seem usually of considerable bulk.

Beekmantown (Calciferous) formation. Just as in the case of the Potsdam beneath, the Beekmantown formation is thickest on the northeast margin of the Adirondack region and thins out to the west and south, though the thinning is less rapid, so that the formation extends much beyond the limits of the Potsdam, being lacking only on the west side of the region. The type locality is at Beekmantown, Clinton co., where the formation is very fossiliferous, but where the section is quite incomplete; in fact, there is no one locality in Clinton county where anything like a complete section of the formation can be obtained.

[1]Am. Geol. April 1903, p.246–49.

For such sections recourse must be had to the district nearer the upper end of the lake. Here the dips are steeper, and there are two localities in Shoreham Vt, where the full section is shown, and the section about Fort Ticonderoga is quite complete also. These sections have been studied in detail by Brainard and Seeley, and the results obtained there applied to other parts of the Champlain region.[1] No other work approaching this for detail and accuracy has been done on the formation in the Champlain region. In their type section at Shoreham they have recognized five subdivisions of the formation, as follows:[2]

		Feet
A Dark iron-gray magnesian limestone, usually in beds 1 or 2 feet in thickness, more or less silicious, in some beds even approaching a sandstone. Nodules of white quartz are frequently seen in the upper layers, and near the top large irregular masses of impure black chert, which, when the calcareous matter is dissolved out by long exposure, often appears fibrous or scoriaceous. Thickness		310
B Dove-colored limestone, intermingled with light gray dolomite in massive beds; sometimes for a thickness of 12 or 15 feet no planes of stratification are discernible. In the lower beds, and in those just above the middle, the dolomite predominates; the middle and upper beds are nearly pure limestone; other beds show on their weathered surfaces, raised reticulating lines of gray dolomite. Thickness		295
C, 1 Gray, thin bedded, fine grained, calciferous sandstone, on the edges often weathering in fine lines, 40 or 50 to the inch, and resembling close grained wood. Weathered fragments are frequently riddled with small holes, called *Scolithus minutus* by Mr. Wing	60	
2 Magnesian limestone in thick beds, weathering drab	100	
3 Sandstone, sometimes pure and firm, but usually calciferous or dolomitic	70	
4 Magnesian limestone like no. 2, frequently containing patches of black chert	120	
Thickness of C		350

[1] Am. Mus. Nat. Hist. Bul. 3:1–23.
[2] *Op. cit.* p.2–3.

	Feet	
D, 1 Blue limestone in beds 1 or 2 feet thick, breaking with a flinty fracture, often with considerable dolomitic matter intermixed, giving the weathered surface a rough, curdled appearance; becoming more and more interstratified with calciferous sandstone in thin layers, which frequently weathers to a friable, ocherous rotten stone....	80	
2 Drab and brown magnesian limestone, containing also toward the middle several beds of tough sandstone..	75	
3 Sandy limestone in thin beds, weathering on the edges in horizontal ridges one or two inches apart, giving to the escarpments a peculiar, banded appearance. A few thin beds of pure limestone are interstratified with the silicious limestone..................................	120	
4 Blue limestone in thin beds, separated from each other by very thin, tough slaty layers, which protrude on the weathered edges in undulating lines. The limestone often appears to be a conglomerate, the small inclosed pebbles being somewhat angular and arenaceous........	100	
Thickness of D..................................		375
E Fine grained, magnesian limestone in beds 1 or 2 feet in thickness, weathering drab, yellowish or brown. Occasionally pure limestone layers occur, which are fossiliferous, and rarely thin layers of slate. Thickness..........		470
Total thickness..................................		1800

Cassin formation. In the upper part of division D and in division E are numerous fossiliferous horizons carrying a rather abundant fauna. These beds are confined to the Champlain valley so far as the immediate region is concerned, and have therefore the same restricted distribution as the following Chazy. In discussing Brainard and Seeley's paper, Professor Whitfield recognizes and emphasizes this point and the considerable differences between these upper beds and the ordinary, sparingly fossiliferous character of the normal Beekmantown. He urges the similarity of the fauna to that of the Quebec group of Canada, argues that these beds have more natural affinity with the Chazy than with the

Beekmantown, and that they should either be placed with that formation or else considered as distinct from either and given a separate name, "as Fort Cassin, or Philipsburg formation, or any other appropriate name."[1] This seems to the writer not only an eminently proper, but really a necessary procedure. The thickness and importance of this group, consisting of the upper 220 feet of division D and the whole of E, is such as definitely to warrant its separate mapping in the Champlain region, and the writer proposes the name "Cassin formation" for it, to make Whitfield's suggestion more precise and definite. The question as to whether the rocks involved are to be classed with the Chazy or with the Beekmantown, or with neither, is not at issue in the giving of the name, the point made being simply that we have here several hundred feet of limestone of definite lithologic and paleontologic character, whose definiteness and importance would seem to warrant its separate recognition and mapping as a substage. In the type section, at Beekmantown, the rocks of this upper horizon are not exposed. The matter will be reverted to on a subsequent page in considering the subdivisions of the Chazy limestone.

When the Beekmantown formation is followed to the south and around into the Mohawk valley, it is found to be much thinner than in the Champlain region, and the upper portion, that which has been separated above as the Cassin formation, is wholly wanting. Prosser has carefully measured a number of sections in this region, but measurements of the full thickness can rarely be made because the formation is seldom cut through to its base, and because it overlaps on the Precambric, thus not presenting its full thickness close to the Precambric border. At Little Falls the formation is 456 feet thick. The deep wells at Ilion and Utica, a few miles farther west and at a somewhat greater distance from the Precambric edge, show a somewhat, but not greatly increased thickness. Eastward from Little Falls the sections in the valley do not get down to the base of the formation, except at Spraker, where Prosser measured a thickness of 500 feet, with the summit not exposed, but the thickness does not vary greatly apparently, though showing some diminution east of

[1]Am. Mus. Nat. Hist. Bul. 3:27–28.

Spraker. The upper beds contain Ophileta and seem of about the same age as the basal part of division D of Brainard and Seeley's section. The upper Cassin beds are wholly lacking in the Mohawk valley, and apparently the latter region was uplifted while they were being deposited on the east. Certainly, the connection between the two areas was broken during this time, confining the Cassin fauna to the Champlain basin, and this seems to the writer an added reason for the separation of the Cassin beds from the normal Beekmantown.

On the north side of the Adirondacks the exposures of the formation are poor and infrequent, the dips are flat, and the breadth of outcrop considerable, with the full thickness not showing on the New York side of the international boundary. Nothing definite is known concerning the thickness in this area, but, as its western limits are reached, in the Thousand islands region, it becomes evident that the formation has greatly thinned. On the western side of the region it is wholly absent, the later Black River and Trenton limestones resting directly on the Precambric, making it perfectly evident that the Beekmantown shore line there lay farther to the west than the present Precambric boundary. Moreover, the imperfect records of the gas wells of Oswego and Jefferson counties, as given by Orton, indicate a thickness of only 200 feet of Beekmantown rocks under cover in the former county, and none at all in the latter, the former wells being 35 miles, and the latter 15 miles distant from the present Precambric boundary.[1] It seems therefore that the Beekmantown sea covered by no means all of the present Precambric region of northern New York, and that the main area left unsubmerged by its waters was on the west and south. On the west the shore was several miles west of the present Precambric edge; on the south it did not extend in more than from 10 to 30 miles beyond the present edge, as the writer has elsewhere shown;[2] much less is known about the rate of overlap on the northeast, but the great thickness of both the Potsdam and Beekmantown formations there would indicate that, by the close of the Beekmantown, the sea must have widely encroached on that portion of the region.

[1] N. Y. State Mus. Bul. 30, p.442, 458.
[2] N. Y. State Mus. Bul. p.77.

Chazy formation. The Chazy rocks are found, at the present day, only on the eastern border of the Adirondack region. Their present distribution gives but little idea of the extent of the sea in which they were deposited, which must have encroached widely over the present northeastern portion of the Adirondacks, from which the deposits have been since removed by erosion. But the formation is wholly lacking on the remaining sides of the region, and can not have been laid down there at all. On the contrary, the Beekmantown land area of the southern and western parts of the region became greatly extended in those directions, shutting out the sea altogether, and leaving merely the eastern area submerged during this time.

Much detailed study has been given the Chazy formation throughout the Champlain valley by Brainard and Seeley.[1] For stratigraphic detail and accuracy this work can not be improved on. It shows that the formation is thickest in the latitude of southern Clinton county; that it rapidly thins southward to utter disappearance at the upper end of Lake Champlain; and that it also thins northward and moreover changes considerably in character in this direction.

Throughout most of the Champlain valley the formation consists essentially of beds of quite pure, clear water limestones, with a surprisingly small amount of land wash of any sort, in itself an indication of considerable width for the basin, much beyond what the present breadth of outcrop would indicate. The formation is thickest on Valcour island, and Brainard and Seeley's measured section there is here reproduced.

Group A (Lower Chazy)

		Feet
1	Gray or drab sandstone, interstratified with thin (or sometimes thick) layers of slate, and with occasional thin layers of limestone at the base, containing Camerella (?) costata Bill.	56
2	The slaty sandstone gradually passes into massive beds, made up of thin alternating layers of tough slate and nodular limestone, containing undetermined species of Orthis and Orthoceras	82

[1]Am. Geol. 2:323–30; Geol. Soc. Am. Bul. 2:293–300; Am. Mus. Nat. Hist. Bul. 8:305–15.

		Feet
3	Dark bluish gray, somewhat impure limestone, in beds of variable thickness; often packed with Orthis costalis Hall, which occurs with more or less frequency through the whole mass. Other fossils are: Lingula huronensis Bill., Harpes antiquatus Bill., H. ottawaensis Bill.(?), Illaenus arcturus Hall, (I bayfieldi Bill.), Lituites sp.(?)...	110
4	Gray, tolerably pure limestone in beds 8 to 20 inches thick, separated by earthy seams, the bedding being uneven. Many layers consist of crinoidal fragments, largely of Paleocystites tenuiradiatus Hall. Near the middle of the mass for a thickness of 10 feet, some of the fragments and small, ovoid masses (Bolboporites americanus Bill.) are of a bright red color.	90
	Making for the total thickness of A..............	338

Group B (Middle Chazy)

1	Impure, nodular limestone containing Maclurea magna Les....................................	25
2	Gray, massive, pure limestone, abounding in crinoidal fragments	20
3	Bluish black, thick bedded limestone, usually weathering so as to show pure nodular masses enveloped in a somewhat impure lighter colored matrix; everywhere characterized by Maclurea magna. Near the middle of this mass for a thickness of about 30 feet, the fossils are silicified and of jet-black color. The more important besides Maclurea, are species of Strophomena, Orthis and Orthoceras.......................	210
4	Dark, compact, fine grained limestone, with obscure bedding, weathering to a light gray. Fossils are infrequent, but at a single locality were collected Orthis perveta Con., O. platys Bill., Leptaena fasciata Hall, Asaphus canalis Con., Cheirurus polydorus Bill., Harpes sp. und., Illaenus incertus Bill., Lichas minganensis Bill., Sphaerexochus parvus Bill., and several undescribed species.....................	20

		Feet
5	Bluish black limestone like no. 3, but less pure, containing Maclurea magna Les., Orthis perveta Con., Strophomena incrassata Hall, Orthis disparilis Con., or O. porcia Bill	75
	Total thickness of B	350

Group C (Upper Chazy)

1	Dove-colored, compact limestone, in massive beds, containing a large species of Orthoceras, Placoparia (Calymmene) multicosta Hall, Solenopora compacta, and a large Bucania	60
2	Dark impure limestone, in thin beds, abounding in Rhynchonella plena; at the base a bed 4 or 5 feet thick is filled with various forms of Monticulipora or Stenopora	125
3	Tough, arenaceous magnesian limestone, passing into fine grained sandstone	17
	Total thickness of C	202
	Aggregate thickness of the Chazy on Valcour island	890

In the same papers the authors show that the diminution in thickness of the formation southward is brought about by disappearance of the lower and upper divisions, so that in the more southerly exposures, only the middle division remains, and that this then rapidly pinches out to disappearance. To the northward the work of the Canadian geologists has shown that the formation rapidly changes in character in that direction, land wash entering much more prominently into its make-up than is the case along Lake Champlain.

It is thus seen that the Chazy is a comparatively local formation, laid down in an arm of the sea which occupied the present line of the Champlain valley, whose upper end limited its waters on the south. Its breadth however, specially on the New York side, was much greater than the present limits of the outcrops would indicate. The southern end of the basin was depressed for a much shorter time than the central portion, and its deposits

are of the middle division. While the Chazy was being deposited, the remainder of the State seems to have been mostly above sea level, and either the same conditions obtained during Cassin deposition or else a barrier was developed between the Champlain and Mohawk basins at this time, preventing the Cassin fauna from reaching the latter area. While the writer is not a sufficiently competent paleontologist to appreciate or discuss the relationships or differences of the Cassin and Chazy faunas, it does seem to him that structurally the Cassin is related to the Chazy rather than to the Beekmantown. The uplift which shut off this basin from the waters of the remainder of the State, and then caused those waters to recede beyond the State's boundaries, took place prior to Cassin deposition, and these conditions persisted during the Chazy, followed by an uplift and then by the great depression which let in the waters of the Black River and Trenton seas over the whole region. It is true that in the Champlain region there is no natural lithologic boundary between the Beekmantown and Cassin, while the basal sandstone of the Chazy does indicate a physical change. But this is a slight one and not to be compared to the greater ones outlined above.

Day Point, Crown Point and Valcour substages. The three divisions of the Chazy are sharply marked off from one another lithologically and seem to the writer equally so paleontologically. Moreover, their thickness and importance over most of the Champlain region seem to warrant their separation in mapping, a matter easy of accomplishment on the scale of the 1 inch maps. They would seem therefore worthy of separate names. Brainard and Seeley's lines of division can not be improved on, as it seems to the writer, and the following names are suggested for them; for division A the Day Point limestone; for B the Crown Point limestone; and for C the Valcour limestone. These are not intended to replace the group name but simply as indicative of the three well marked substages of the group. Division A is well shown along the lake shore in the northern part of Peru township, is exceedingly fossiliferous there, and in the near vicinity both contacts are to be found, the upper at Bluff point, the lower on

Valcour. The lower part of division B is magnificently shown on Bluff point, in the southern part of Plattsburg township, and the full thickness, except for occasional small gaps, is well exposed in the Chazy wedge between the Beekmantown and Plattsburg faults in the northern portion of the town.[1] Both contacts show here, and large quarries are opened in the rock. The upper division is splendidly shown on Valcour island, with exhibition of both contacts. It is perhaps equally well shown in Chazy township, and the middle division is also well displayed there with full thickness; but, since the name is used for the full formation, it can not be applied to a substage.

Lowville (Birdseye) limestone. In the Mohawk valley the Beekmantown rocks are in many places capped by the thin limestone formation to which the above name has been given. The rock is mostly a gray to drab, brittle, quite pure limestone, usually in rather large massive layers from 1 to 4 feet thick. though much of it is thinner bedded also. It is everywhere penetrated with the vertical, branching tubes of the fucoids which are so characteristic of the formation, which are usually filled with crystalline calcite, and whose cross sections on many surfaces give rise to the bird's-eye appearance which gave the original name to the formation.

Its distribution is erratic and is a matter of considerable importance. It is limited to the south and west sides of the Adirondacks, in the former situation resting on the Beekmantown, and in the latter apparently on the Precambric, though no actual contact is exposed in the whole region, so far as the writer is aware. The drift is very heavy in that region, and little or no work has been done on the rocks since the reports of Emmons and Vanuxem were published. Apparently the formation extends through Herkimer, Oneida, Lewis and Jefferson counties and in considerable strength, but with its base nowhere showing. Toward the north, in Jefferson, the Beekmantown and Potsdam formations begin to appear thinly underneath. Emmons reports a thickness of 30 feet near Watertown, which is probably simply an estimate. This whole western contact line is in need of careful study.

[1] 15th An. Rep't State Geol., p.556.

Returning to the south side, Prosser's sections through the Mohawk valley,[1] together with the supplementary ones of the writer about Little Falls, are sufficient to show well the bulk and distribution of the formation there. Along East and West Canada creeks the thickness is between 20 feet and 25 feet, beneath which, in most places, there is a gradation into the Beekmantown below through a series of passage beds of intermediate composition and appearance, which have about the same thickness as the Lowville itself. In the district between the two creeks the formation has the same general character though locally the passage beds are lacking and the formation thins. At Canajoharie, 17 miles down the river from Little Falls, the Lowville is absent, the unconformity at that horizon being more plainly marked here than at any other locality. Three miles beyond, about Spraker, the conditions are the same. At Tribes Hill, halfway between Fonda and Amsterdam, and 13 miles below Spraker, the Lowville has reappeared, though no complete section of it has been published, and the passage beds at the base are lacking. About Amsterdam and Hoffman the formation is usually present but very thin, not exceeding 8 feet, seldom reaching 5, and often falling to 2 feet, showing much variation over short intervals and sharply separated from the Beekmantown. East and northeast from this point it is usually absent though occasionally seen, and the last reported occurrence seems to be that near Saratoga, where the thickness is but 2 feet. In this neighborhood the Beekmantown is also very thin, apparently marking the place where the rising of the land during Beekmantown times was first felt, and where the separation of the Champlain and Mohawk Beekmantown basins was first effected.

The prominent features brought out by these sections are: the resting of the Lowville on the Precambric along the western side of the region, the conspicuous unconformity at Canajoharie, the passage beds to the Beekmantown in the West Canada creek region and the great irregularity of the formation eastward from there, with its final disappearance about Saratoga. It is as plainly confined to the south and west sides of the region as the Chazy and Cassin are to the east side; and was thus deposited in

[1] 15th An. Rep't State Geol. p.619–59, and N. Y. State Mus. Bul. 34.

a wholly different basin. On the west its waters encroached farther on the Precambric land than the Beekmantown waters did. On the south it was very irregularly deposited, owing to slight unevenness of the floor. It is not certain whether it was contemporaneous with the later Chazy or followed that in time. Its fluctuations in thickness, its occasional absence, and its sharp contact line with the Beekmantown through most of the Mohawk valley give physical evidence of a considerable time gap between the two formations, during which some slight flexing and erosion of the Beekmantown rocks took place, and during which the Cassin and Chazy rocks were being deposited in the Chazy basin. This evidence is so clear that it would seem that the apparent passage beds in the West Canada creek district can not be actually such, but belong with the Lowville. The Lowville depression seems to have invaded the district from the southwest, and these beds represent an older stage of the formation than do any of those found to the eastward in the Mohawk valley.

Black River limestone. This formation is found on all sides of the Adirondacks, though locally lacking in the Mohawk valley. Throughout the Champlain valley region it shows a massive. basal layer of pure, dove-colored limestone which much resembles the Lowville except that it lacks the characteristic calcite tubes. Above this layer the entire formation consists of massive layers of solid, brittle, pure, black limestone, breaking with conchoidal fracture. About the lower end of Lake Champlain it ranges from 30 feet to 50 feet in thickness. Southward along the lake the writer has not seen the sections, but White reports a measured thickness of 71 feet, 3 inches on Crown Point peninsula, the greatest observed thickness reached in the State.[1] From this point it thins toward the south, as do all the Paleozoic formations of the region. In Saratoga county it has an intermediate character, containing layers which resemble the Lowville, Prosser's sections at Glens Falls showing a thickness of 27 feet for the two combined. This seems however an exceptional thickness, most sections in the vicinity being vastly thinner. Coming around into the Mohawk valley, the formation ranges from 5 to 9 feet in thickness about Amster-

[1]White, T. G. Geol. Soc. Am. Bul. 10:457.

dam and Hoffman, as Prosser has shown, and is in part massive, in part thin bedded and lumpy. At Tribes Hill there is a 3 foot lumpy layer between the Lowville and Trenton which he refers doubtfully to the Black River. At Canajoharie and Spraker the Black River is absent, as is the Lowville, flat Trenton beds lying directly on slightly folded Beekmantown. In the district about Little Falls it is sometimes present, but more frequently absent, varying rapidly within short distances. Thus at Ingham Mills Prosser gives two sections, which the writer has also seen, in one of which there are 5 feet of black, lumpy limestone, capped by an 18 inch stratum which is lithologically like the Lowville beneath. Near at hand, in the second section, the succession is the same, but the Black River is only 2 feet thick, though it is followed by the same recurrent Lowville layer, above which the Trenton appears. At the old kiln, $\frac{1}{4}$ mile to the north, is a still better section, showing 8 feet of fossiliferous Black River limestone, underlain by a thickness of 10 feet of Lowville beds, and capped by the Trenton [pl.4]. As in all cases hereabout, the rock is quite thin bedded and lumpy with shale partings. Northward from Little Falls the formation is seldom present and then is very thin; the same is true in the many sections about Middleville. About Newport it has reappeared, with a thickness of 5 feet to 6 feet, thin bedded and lumpy as at Ingham Mills. Followed northwest from here it thickens, and becomes persistent and massive. T. G. White reports a thickness of 20 feet at Boonville and Lyons Falls, respectively 25 miles and 35 miles northwest of Newport, in the Black river valley.[1] It is here for the most part quite massive, though somewhat shaly in its upper portion.

Farther to the northward, there is little or no accurate published information concerning the formation. Emmons gives the thickness at Watertown as from 7 feet to 8 feet, and the rock somewhat lumpy, though without shaly partings.[2] All along this side of the region the glacial deposits are exceedingly heavy, making rock outcrops very exceptional and meager. There seems however, no reason to doubt that the Black River

[2] N. Y. State Mus. 51st Rep't, 1: r27–29.

[2] Geol. N. Y. 2d Dist. p.386.

Plate 4

Quarry face at bridge north of Ingham's Mills, showing 10 feet of Lowville (Birdseye) limestone at base, followed by 8 feet of thin black limestone bands with shale partings, of Black river age, and capped by 5 feet of Trenton limestone

extends along it unbroken, with the Lowville beneath. Hence the Black River sea surrounded the region on all three sides with apparently unbroken connections, much diminishing the size of the former land areas of the region, even that of Beekmantown times, which was the smallest of those that preceded it. The present outcrops of the Mohawk valley are near the old shore line, and the irregular, ridgy character of the bottom was the cause of the variations in thickness of the formation there. Had erosion cut somewhat deeper, in other words, were the exposures of the formation on a line somewhat south of the present, it would undoubtedly extend east and west unbroken. The Beekmantown pebbles in the Black River, in the Tribes Hill-Amsterdam region, reported by Vanuxem and by Prosser, are very significant as showing the near vicinity of the shore line.[1]

Trenton formation. The Trenton formation may be said to show a general uniformity in lithologic character all about the Adirondack region, though with much variation in detail from place to place. Instead of the quite pure, massive limestones of the Chazy and Lowville formations, the major portion of the Trenton is found to consist of thin bedded, black, shaly limestones, often with partings of black, calcareous shales, the entire formation being thus contaminated with a certain amount of land wash in the shape of fine mud. The limestones are usually hard and brittle, with conchoidal fracture, though becoming thin bedded and shaly, and even the heavier beds split thinly on weathering.

In all sections there is considerable gray, rather coarsely crystalline, fairly pure, very fossiliferous limestone, usually thin bedded though sometimes becoming fairly massive. While sometimes fairly persistent for considerable distances, such beds are usually lens-shaped masses of restricted lateral extent, entirely surrounded by the black calcareous muds of the ordinary character. Beds of this sort seem less local and more persistent in the Mohawk than in the Champlain valley, as has been pointed out by White, and constitute a larger portion of the formation in the former situation, indicating less local variation in the

[1] Geol. N. Y. 3d Dist. p.44; 15th An. Rep't State Geol. 1: 653.

conditions there.[1] In the Champlain valley they are more limited to the basal portion of the formation than is the case along the Mohawk.

In the lower Champlain region the writer knows of no continuous section of the Trenton, and its thickness there is largely a matter of conjecture. A minimum limit may be assigned, but no maximum, and there are beds, apparently Trenton, whose stratigraphic horizon is yet unknown. In the bed of the Little Chazy river, at Chazy village, the lower 150 feet of the formation are shown, directly overlying the Black River beds, and consisting at the base of slaty layers, alternating with beds of hard, brittle, blue black limestone; the major portion of the section being however constituted of the limestone, the slaty layers vanishing, and in this portion are occasional layers of the gray, crystalline limestone which are masses of fossils.

Along the lake shore northward from Bluff point, Trenton rocks outcrop continuously for $\frac{1}{3}$ mile, being separated from the Chazy limestones which constitute the point by a fault. Because the outcrop surface is horizontal, and the dip varies much in amount and direction, it is a difficult section to measure accurately, but a thickness of at least 100 feet is involved. At the base are many of the coarse gray, fossiliferous layers, but these die out toward the summit, and the rock becomes shaly. This section seems to overlap, in part, the section at Chazy, but to show higher beds than any seen there.

On Crab island, a mile northeast from Bluff point, out in the lake, an excellent Trenton section is exposed which is practically a continuous one. The exposures comprise part of a low, northerly pitching anticline, the island is nearly a half mile long, and the writer has estimated the thickness of the section at 200 feet. Brainard and Seeley state the thickness to be over 200 feet, and the writer is confident that White's figure of less than 100 feet falls far short of the truth.[2] The lower part of the section, at the south end of the island, shows much of the gray, crystalline, fossiliferous limestone. Following this are thin bedded, slaty layers, but the upper part of the section, comprising more than

[1] Geol. Soc. Am. Bul. 10:455.

[2] Cushing, H. P. 15th An. Rep't State Geol. p.514; Brainard & Seeley. Am. Mus. Nat. Hist. Bul. 8:308; White, T. G. Geol. Soc. Am. Bul. 10:457.

Plate 5

Black marble and overlying thin bedded limestone in a quarry on the north side of the Hudson river at Glens Falls

half of its thickness, is formed of blue black, brittle, somewhat muddy limestones, carrying a trilobite, cephalopod, lamellibranch fauna, as distinguished from the abundant brachiopod fauna of the gray limestone. These rocks are nearly on the strike of the section north of Bluff point, and there is unquestionably some overlap in the two; but, as the larger part of the Crab island section is of higher beds than any shown in the other, these three sections can only be fitted together by the most painstaking paleontologic work, perhaps not even by that. The writer is confident that the upper beds on Crab island are from 300 feet to 350 feet above the base of the formation. These are the three best sections of the Trenton which the writer has seen toward the lower end of the lake. They indicate a large thickness for the formation, but give no clue to the amount that may be lacking above the upper beds of the Crab island section.

In a recent report on the geology of Grand isle, Vermont, Professor Perkins has described an interesting section which shows that there is no sharp, lithologic break between the limestones of the Trenton and the overlying black shales of Utica age, but rather an imperceptible gradation from the one into the other, forming a series of passage beds.[1] These consist of rapidly alternating shales and limestones, with a comparatively steady increase upward in amount of shaly matter. The thickness of these beds is not stated, possibly because the section is not sufficiently complete, possibly because their recognition as a separate lithologic unit simply increases the difficulty of constituting boundaries by making two vague horizons instead of one. The beds of distinctively intermediate character seem however to be of considerable thickness.

Along the shores of Cumberland head, on the New York side of the lake, is an excellent, though much disturbed, section, consisting of blue black slaty limestones and calcareous shales, with some firmer limestone bands. These rocks are much faulted and squeezed, and somewhat folded, with much development of slaty cleavage at a high angle with the bedding planes. These rocks extend along shore northward to beyond Point au Roche, in Beekmantown. Dr White states that similar rocks occur on

[1] Rep't Vt. State Geol. 1901-2, p.167-68.

Grand isle, directly opposite Cumberland head, and it would seem that these are the rocks referred to as transition beds by Professor Perkins.[1] From the study of the fauna White seems to be somewhat uncertain as to the precise horizon, and speaks of it as "very high Trenton or Utica".[2] Since the passage beds on Grand isle are demonstrably such, a comparison of their faunas with those of the Cumberland head rocks should settle the question of stratigraphic equivalency. But, if these be actually the passage beds, their thickness is apparently large, though the Cumberland head section is so greatly disturbed that little exact idea as to its thickness can be obtained. The lithologic character would seem to agree with such a reference.

Published data of precise character in regard to the thickness and nature of the Trenton toward the upper end of the lake, are not numerous. On the Vermont shore, across the lake from Port Henry, Brainard and Seeley give a measured thickness of 314 feet for the Trenton, the exposures being a continuation of the section on Crown point, on the New York side.[3] It is in this section that the Black River limestone attains its maximum thickness of 71 feet. White says of it that, on Crown point, above the Black River, is a continuous series of 100 feet of alternating, compact, sandy and shaly layers, all quite thin, containing the lower and middle Trenton fauna of the region.[4] It is not clear from their account, whether Brainard and Seeley include the Black River in their statement of the thickness of the Trenton or not. White states that there is a hiatus between the upper Trenton bed exposed and the Utica outcrops beyond, but makes no statement in respect to its amount. Nothing is therefore apparent as to the transition beds in the region. But, unless a fault intervenes, it would seem that they can not be of very considerable thickness.

At Larrabee point, opposite Fort Ticonderoga, White gives the Trenton a thickness of 110 feet, the section terminating in that formation, though Utica shale appears in place not far away.[5] The lithologic character of the formation is not touched on, and we

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[1] *Op. cit.* p.114.
[2] *Op. cit.* p.460.
[3] Am. Mus. Nat. Hist. Bul. 8:313.
[4] Geol. Soc. Am. Bul. 10:457.
[5] *Op. cit.* p.456.

Plate 6

Trenton limestone in a quarry at Howland's Mill, Saratoga co.

are left in doubt as to how large a portion is shown, and whether or not a fault intervenes between the Trenton and Utica, as is very likely. Faults so abound in the Champlain region that the finding and measurement of complete sections is a matter of great difficulty, so abound in fact that the geologist is more often called on to demonstrate their absence than their presence. If there is none here, the Trenton has obviously thinned greatly southward.

In the country between Lake Champlain and the mouth of the Mohawk, exposures of the formation are interrupted and fragmentary. At Glens Falls Prosser has measured several Trenton sections, but all terminate in that formation, so that the full thickness is not shown.[1] The greatest measured thickness in the vicinity is 63 feet, the basal portion consisting of very massive, black, fine grained beds, while above is much thinner bedded material, with some intercalation of gray, crystalline layers. If the total thickness were much greater than that shown in this section, it would seem that thicker sections would surely be forthcoming, and their nonappearance seems therefore significant. No passage beds seem to have been noted, but whether their absence is due to nonexposure of the proper horizon or not, is not clear.

Similarly, about Saratoga, Prosser's sections show a maximum measured thickness of 37½ feet for the Trenton, mostly thin bedded, but some massive, and here again the summit is not exposed, so that the entire thickness may be in excess of that amount, but is not likely to be greatly in excess [pl.6].

While the sections at these two localities are not decisive as to thickness, it seems probable that the entire amount can not greatly exceed the figures given, and hence that the formation has rapidly thinned in this direction.

In the lower Mohawk valley, in the Amsterdam-Hoffman region, Prosser and Cuming's sections afford accurate data concerning the formation.[2] They show considerable variation in thickness, the maximum amount being 36½ feet in the section at Morphy's, while the minimum is 20 feet. The lower 6 to 8 feet are of massive, often crystalline, limestone, while the remainder consists of thinner bedded and dark colored, more shaly material.

[1]N. Y. State Mus. Bul. 34, p.480–82, pl.8.

[2]15th An. Rep't State Geol. p.647–59; N. Y. State Mus. Bul. 34, p. 419–64.

Coming westward, at Tribes Hill, a measured 40 feet of Trenton is the section record, and it terminates in the formation, so that the actual thickness may be somewhat greater. At the base is a 12 foot thickness of massive, dark blue limestone, with some crystalline lenses, followed by 11 feet of thin bedded, uneven, gray crystalline and dark colored limestones, which are capped by 17 feet of thin bedded, uneven, dark blue limestone.

At Spraker the formation has thinned to 17 feet, both contacts showing, and consists of thin layers of dark blue limestone, apparently representing the upper part only of the Tribes Hill section and with the Lowville and Black River both lacking as well. Three miles west, at Canajoharie, the thickness and lithologic character are the same, and here the unconformity between the Beekmantown and Trenton is also plainly marked by a discordance in dip [pl.7].

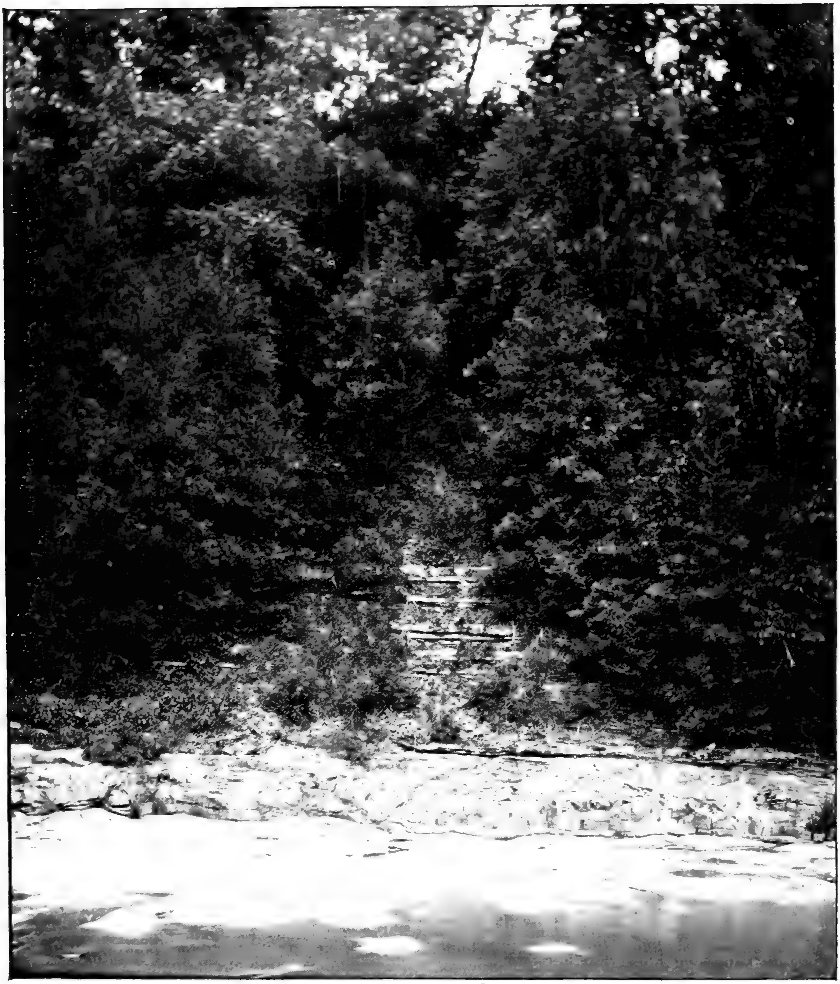
In the district about Little Falls the formation shows considerable variation in thickness, with rapid increase westward. On East Canada creek it is about 50 feet thick, with the Lowville always, and the Black River sometimes appearing beneath. Here it consists largely of gray, crystalline, fossiliferous layers, these being capped by thin bedded, blocky, black limestones, which become intercalated with shales and grade into the Utica above, the distinctive passage beds being of about the same thickness as the ordinary Trenton.

At Little Falls Prosser has assigned 104 feet to the formation, though but little of it is exposed in his section. The writer's measurements north of that point show an average of 80 feet of thickness, with again an equal amount of passage beds above.

Along West Canada creek, between Herkimer and Middleville, the Trenton ranges from 100 feet to 120 feet in thickness, the gray, crystalline, thin bedded type largely predominating in the lower half of the section and the dark colored type in the upper. Here also is an approximately equal thickness of passage beds, alternate shale and limestone layers, the limestone being identical in character with the dark colored Trenton type, and the shale being indistinguishable from the ordinary Utica.

Northward from Middleville there are many exposures of the Trenton, but most are of merely the lower portion, and there is

Plate 7



North bank of creek behind Canajoharie N. Y., exhibiting the relations of the Trenton limestone

no good continuous section. Northwestward also, about Newport and Poland, the sections stop in the lower Trenton, while away from the creek valley the drift cover is excessive. There is however a very good section in Rathbone brook, near Poland. White measured the section here and states its thickness to be 138 feet, with the Black River in place below.[1] He was unable to determine how great a thickness at the base should be regarded as being below anything shown at Trenton falls, where the base of the formation is not shown. The section also terminates in the Trenton and hence gives only a minimum value to the thickness. The incompleteness of the section hereabout is exceedingly unfortunate, since in the gorge of West Canada creek at Trenton falls, the type locality of the formation and distant only 14 miles from Middleville, the section shows a thickness of 275 feet (Prosser), or 284 feet (White), with neither base nor summit exposed.[2] Reference may be made to their papers for the details of the section, which consists mainly of thin bedded, dark blue limestones, with considerable admixture of the gray, crystalline beds, and with occasional massive layers; the whole capped by the 26 feet of massive, gray layers at Prospect [pl. 8 and 9]. Underneath this cap considerable shale is intercalated with the thin limestones through a thickness of 60 feet, giving a lithologic combination quite like that of the passage beds elsewhere. Nothing can be learned concerning these in the vicinity, unfortunately. According to White the lower portion of the Rathbone brook section underlies the base of the section at Trenton falls, but he does not hazard a suggestion as to the actual thickness involved. It seems however quite safe to say that the Trenton at Trenton falls is approximately 300 feet thick, more than double its thickness at Middleville, 14 miles away to the south of east. Only 27 miles farther to the southeast lies Canajoharie, with its 17 foot thickness for the limestone, the minimum for the State. Some of the latter diminution is due to overlapping unconformity, the base disappearing, but in either case it is obvious that the increase west from Middleville is more rapid than is the decrease eastward. Also that the increase in thickness is upward, implying that the

[1] N. Y. Acad. Sci. Trans. 15:84.

[2] 15th An. Rep't State Geol. p.626 and footnote.

muds of the passage beds and Utica advanced on the region from the east, and Trenton conditions persisted longer westward. In other words, that, while the upper Trenton was accumulating in comparatively clear waters, in the Trenton falls region, incursions of mud were producing the lithologic combination of the passage beds about Middleville and eastward, while yet farther east shales were being laid down. This is by no means a new suggestion, though the stratigraphic evidence for it has not been so marshaled hitherto. Even if it be granted, it does not fully explain the sudden increase in thickness at Trenton falls, when compared with the much more trivial variations which characterize the whole length of the Mohawk valley below Canajoharie.

Concerning the formation along the west side of the Adirondacks, our knowledge is very fragmentary. As has been stated, the heavy drift cover on this side of the region is an effective bar to satisfactory areal work. Well to the north, about Watertown, conditions are much better, and the Trenton is magnificently shown. Emmons's descriptions show that it has the same lithologic characters here as at Trenton falls and elsewhere, consisting partly of dark, fine grained, and partly of gray, crystalline limestone, the former often interleaved with shales; also that often the summit is gray and massive, as at Trenton falls, which is not the case in the Mohawk and Champlain valleys. He states the thickness at Watertown to be about 300 feet, which, judging from his estimates of thickness of the rocks in other parts of the second district, is likely to be an underestimate.[1]

Quite fortunately the gas wells drilled within the past 20 years to the west and southwest of the region help to bridge the gap in the sections and furnish important data in regard to the thickness of the formation. The wells at Pulaski and Sandy Creek in Oswego county, which are 55 miles northwest of Trenton falls, and respectively 25 and 32 miles to the west of south of Watertown, have been described, and the sections interpreted by Professor Orton.[2] As is often the case, it is difficult to determine precise formation boundaries from the records, owing to a variety of causes. At Sandy Creek the thickness of the Trenton is uncertain but seems surely as much as 600 feet. At Pulaski the wells

[1] Geol. N. Y. 2d Dist. p.387–88.

[2] N. Y. State Mus. Bul. 30, p.434–48.

Plate 8

Trenton falls. View of the "Narrows" from lower end with Sherman fall in the distance

were drilled deeper, and from their records Orton constructed a generalized section for the vicinity, which allots a thickness of 600 feet to the formation (inclusive of the Black river and Lowville), and 200 feet to the Beekmantown beneath.[1] At Stillwater, 10 miles southeast of Pulaski, he indicates a thickness of 670 feet for the Trenton, and no allowance is made for the Beekmantown, which is surprising and suggests the query whether the Trenton has not been thickened at its expense. Here also the upper 300 feet are significantly referred to as "White Trenton" and the lower portion as "Dark Trenton," an arrangement of interest when compared with the type section.

A few wells are also reported on in Jefferson county, but the records given are very fragmentary.[2] In Adams township, next southeast of Watertown, three wells were drilled to the Precambric, which was reached at from 915 to 960 feet. Except for a few feet of drift the wells began in the Trenton and very near its summit. It seems incredible that the formation should be 900 feet thick here, but this includes the Black River and Lowville, and, in all probability, at least a small thickness of the Beekmantown, though it is not certain that that formation is here present. It is found however in outcrop not many miles away to the northeast, though it is not thick. However this may be, and making the most generous allowance possible, there yet remains a huge thickness which must be ascribed to the Trenton proper.

Notwithstanding their imperfections, these sections indicate with clearness that the thickness of the formation at Trenton falls is not a mere local matter, but that it is held, and much increased to the north, on the west side of the Adirondack region. As the same records show, the overlying Utica rapidly thins in the same direction.

In the Mohawk valley, west from Herkimer, the drill has also given corroborative evidence.[3] In the well at Ilion, only 3 miles west of Herkimer, the section shows 105 feet of Trenton, about what should be expected from its measured thickness along West Canada creek between Herkimer and Middleville. At Utica, 12 miles farther to the north of west, the Trenton is certainly 330

[1] *Op. cit.* p.442.

[2] *Op. cit.* p.456–59.

[3] Prosser, C. S. Am. Geol. 25:131–49; Geol. Soc. Am. Bul. 4:100.

feet thick, and perhaps more, the line between the Trenton and Beekmantown being difficult to draw with precision in that well. At Vernon, 17 miles west of Utica, 350 feet of the well section are assigned to the Trenton, and at Rome, 11 miles northwest of Utica, 375 feet. These thicknesses are not so great as those farther to the north, but the sudden increase in thickness between Ilion and Utica is quite analogous to that between Middleville and Trenton falls, along the more northerly line. At Chittenango, 35 miles west of Utica, the drill passed through 636 feet of apparent Trenton, and rested in that rock, a thickness directly comparable with that shown in Oswego and Jefferson counties.

Utica formation. This formation is, as a whole, surprisingly homogeneous all about the Adirondacks, consisting of fissile, black, somewhat calcareous, clay shales, which, like most carbonaceous shales, tend to split thinly and evenly and to have a somewhat slaty character. They become usually more fissile and less calcareous above, while below thin bands of shaly, black limestone commence to appear and increase in abundance, forming more or less of a transition to the Trenton beneath. Definite passage beds of the sort, of considerable thickness, are often found, but the evidence is not decisive as to whether they are, or are not, everywhere present in force. More likely they are not, and this seems specially probable on the west side of the region, and also in the lower Mohawk valley; whereas in the Champlain valley and the upper Mohawk region they have much importance. These beds are also a mixture faunally, the rather restricted fauna which characterizes the pure Utica occurring with a considerable number of Trenton forms, so that the line of demarcation between the two formations will vary greatly, according as it is drawn at the first appearance of the Utica fauna, on the one hand, or at the final disappearance of the Trenton fauna on the other. The case is one where it seems certain that the two contrasted faunas were living in the same basin at the same time, each in situations where the conditions were favorable, and each under different sorts of conditions; and that the one set of conditions increased in area occupied, and its fauna spread, at the expense of the other.

In the Champlain valley it is difficult to arrive at any precise notion regarding the thickness of the formation. It is the

Plate 9

Trenton falls. Sherman fall from above the "Narrows"

youngest of the Paleozoic formations there exposed, it is likely that no considerable thickness of any younger deposit was ever laid down on it, and hence it has been largely removed by erosion, more so than any of the others, so that its summit nowhere appears. The question is made more complicated by the faulted character of the region and by the fact that the disturbances here have folded and cleaved the Utica more than they have any of the subjacent rocks. White reports the formation as having a thickness of several hundred feet throughout the valley, but, in making this statement, includes the Cumberland head rocks, whose fauna he elsewhere states to be a transition one.[1] If they are to be included, the writer's estimate, based on work in the same region, would coincide. A few miles east of the lake shore in Vermont, Brainard and Seeley at Shoreham, and Walcott at Highgate Springs, have inferentially indicated a large thickness for these shales by calling their upper portion Hudson River, instead of Utica. The deposits at the latter locality would seem however to belong to the Levis, rather than to the Chazy basin. In the discussion of White's paper, Ami urged that the Utica about Ottawa is but 75 feet in thickness; and it may well be that its thickness in the Champlain valley has been overestimated. Adequate notions concerning the actual amount are not to be had as yet. So far as New York is concerned, the fauna of the Cumberland head shales seems to be confined to the lower Champlain region.

In the Mohawk valley we meet for the first time with overlying formations, so that the Utica summit is exposed, and definite evidence in regard to its thickness can be obtained. Cumings has shown, in eastern Montgomery county, a thickness of the Utica of from 1000 to 1200 feet.[2] Thence westward to Little Falls no measured sections have been carried through the formation, so far as the writer is aware. South of the Mohawk, near Little Falls, the writer has measured over 600 feet of the formation, without reaching its summit. Walcott gives 710 feet as the thickness shown in the Campbell well, near Utica.[3] These go to show that the thickness in the Mohawk valley is

[1] Geol. Soc. Am. Bul. 10:456–57.
[2] N. Y. State Mus. Bul. 34, p.466.
[3] Geol. Soc. Am. Bul. 1:347.

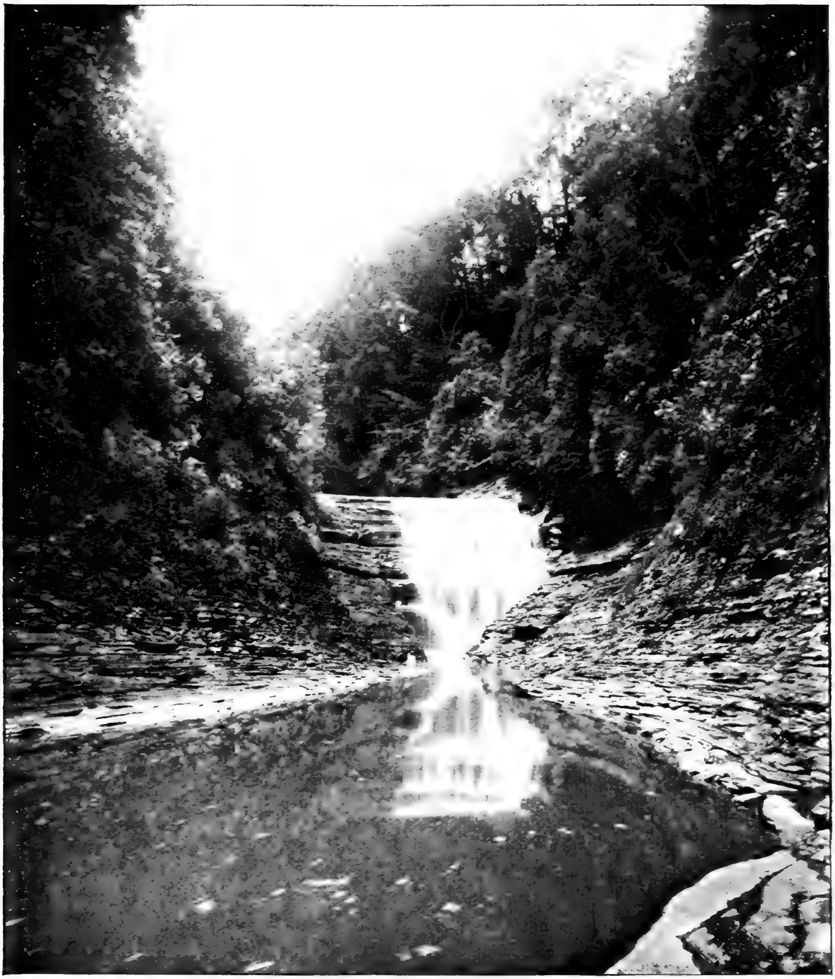
great, and also that it diminishes somewhat westwardly, so that it has but little over half the thickness about Utica that it has in eastern Montgomery county.

North and west from Little Falls, it will be remembered that the Trenton thickens, rapidly and suddenly, and it is of interest to note the coincident thinning of the Utica. Commencing at the north, Walcott's measured section along Sandy creek, in Jefferson county, shows the Utica to be 180 feet thick, with an additional 100 feet of passage beds to the Lorraine shales above.[1] In Oswego county Orton reports, at Central Square 729 feet of shales (Pulaski and Utica) between the Oswego sandstone and the Trenton, of which 150 feet are ascribed to the Utica; at Oswego 597 feet of shales in the same interval; at Stillwater 643 feet, of which 113 are thought to belong to the Utica; about Pulaski 300 feet to 500 feet of shales, of which 100 feet to 250 feet represent the Utica thickness; and at Sandy Creek (Oswego, not Jefferson county), 250 feet to 300 feet of Utica.[2] These are vastly thinner than the Mohawk sections and overlie in general from 450 feet to 650 feet of Trenton, usually in a definite inverse ratio, a strong indication of the contemporaneity of the upper Trenton and lower Utica in the contrasted districts. Moreover, Prosser shows 1020 feet of shales in the Vernon well, of which 300 feet are Utica, overlying 350 feet of Trenton; 873 feet in the Chittenango well, of which 233 feet are Utica, overlying 60 feet of passage beds and some 600 feet of Trenton; 505 feet at Baldwinsville, north of Syracuse, the amount to be attributed to the Utica not being stated; and at Auburn 557 feet of shales, the drill resting in the Trenton 240 feet below its summit.[3] These show definite Trenton thickening, and Utica thinning westward, though the change is more gradual than it is to the north.

Lorraine formation. While no paleozoic rocks younger than the Utica shale are found in sufficient proximity to the Adirondack region to justify any detailed discussion of them in a consideration of Adirondack rocks, yet some of them are sufficiently involved with its past history, as will appear beyond, to deserve some notice.

[1] *Op. cit.* p.348.
[2] N. Y. State Mus. Bul. 30, p.456, 449, 442, 437.
[3] Am. Geol. 25:152, 161.

Plate 10



Falls over Utica slate in the ravine behind Canajoharie N. Y.

On the south and west sides of the region, the Utica shales are overlain conformably by a group of shales and sandstones, often with passage beds between; and the group has usually a large thickness, as the section and well records just quoted demonstrate. There is no direct evidence that equivalent rocks were ever deposited in the Chazy basin of the Champlain valley, but neither is there any weighty evidence that they were not. South of the Mohawk, however, and all along the west side of the region, they appear in force. The above quoted records show that the formation thins westward through the Mohawk valley, is thinnest at Utica, where only its base is present, and thence thickens rapidly to the north and west. Walcott has given a thorough discussion of the evidence, showing that it argues for a shallowing of the sea along the Utica meridian early in Lorraine times, thinning the section there, and preventing thereafter a commingling of the western (Lorraine) fauna, with the forms to the eastward of the barrier, which hence separated the eastern Mohawk basin from that of the interior.[1] It is by no means improbable that this uplift at Utica is but part of a greater movement, which extended thence to the northeast, bringing much, if not most of the Adirondack region above sea level and causing also cessation of deposition in the Chazy basin.

The great thickness of the Lorraine rocks, both in the eastern Mohawk region and in Jefferson and Oswego counties, together with the fact that their present line of outcrop is owing to long continued, surface erosion, and that the effect of this erosion is to cause the line of outcrop continually to recede from the Adirondacks, sufficiently indicates that in the past they must have extended in over them, likely for several miles, and that in some considerable thickness; and that during Lorraine times a considerable area, specially on the northwest and the southeast, remained yet submerged, in spite of the uplift described above. In addition, it is by no means impossible that some of the later Siluric rocks may have overlapped on the southern and western margins of the region, though this is much more open to question than is such a former extension of the Lorraine rocks. Certainly, the general tendency to subsidence over the district, initiated in

[1] Geol. Soc. Am. Bul. 1:344–50.

Cambric times, was checked and replaced by the contrary tendency during Lorraine times, a tendency which has, in the main, persisted to the present.

Helderberg submergence. On the south and west of the Adirondack region the Lorraine rocks are successively overlain by the Medina, Clinton, Niagara, Salina and Waterlime deposits. These are more likely to have overlapped on the west side of the region than elsewhere. On the south they thin and disappear in going eastward, showing that they are approaching a shore line in that direction, and that the lower Mohawk region was not receiving deposit during most of the interval. Then ensued a change at the extreme east, a considerable depression being formed there, in which marine limestones accumulated, whose fauna entered the basin through some connecting channel with the eastern sea. These rocks do not extend westward as far as the upper Mohawk region, showing that that district did not participate in the depression, or else that a barrier was formed there, separating the eastern basin from that to the west, waterlime conditions persisting in the latter after they had been brought to an end in the former. From Albany these rocks extend far south into the Appalachian region, as deposits in a long, trough-shaped basin. As to the northern limits of that basin, we are in ignorance, the deposits having been swept away by erosion; but, since it is known that the present line of the St Lawrence was also depressed during that time, deposits of that age occurring on St Helen's island, near Montreal, it is rendered quite likely that the Champlain and upper Hudson valleys were also involved, forming a channel which furnished a connection with the outer sea by way of Montreal. If such were the case, the subsequent removal of the deposits has obliterated all the evidence on which a demonstration might be based. There was some connecting channel with the outer sea; there may have been more than one; the line suggested would furnish a natural route.

Summary of early Paleozoic oscillations of level. The evidence which is given by the distribution, character and thickness of the several Paleozoic formations which were deposited on, and around, the Adirondack region, as to the oscillations of the land surface,

has been treated in some detail in the foregoing pages, but a concise summary of it may well find a place here.

The Potsdam is confined mainly to the north and east sides of the region. It comes around into the Mohawk region, but is thin there and fades out to a vanishing point about midway of the valley. It does not appear at all on the west side of the territory. It is thickest on the northeast, in Clinton county, and there alone is any great thickness of its peculiar, basal portion to be found. To the south and west the formation thins by disappearance of this base, and it would seem therefore that deposition must have commenced on the northeast and advanced progressively westward and southward, so that by the close of the Potsdam the northeastern district had undergone large submergence, whereas on the southwest the shore line was yet outside of the present Precambric margin, and the amount of subsidence had been trifling; that is, that there existed a large, unsubmerged area on the south and west at the close of Potsdam time.

The formation was laid down on a comparatively even floor of older rocks, whose evenness was mainly due to previous protracted wear on it while a land surface; but, in spite of the *comparative* evenness, the floor shows much minor irregularity, whose amount seems to increase with increasing thickness of the overlying Potsdam. All the workers on the north and east sides of the region have observed and commented on the irregularity of the floor, which sometimes amounts to some hundreds of feet. In the Mohawk valley region the floor seems to have been exceedingly even and flat, much more so than on the north. Since the former was barely, or not at all submerged by the Potsdam sea, while the latter was early invaded by it, the one did and the other did not experience subaerial erosion during Potsdam time, this furnishing an obvious reason for greater smoothness in the former, though it may not be the whole reason.

The upper division of the Potsdam would seem plainly to be a marine sand deposit. Quite likely this is true of the middle division also, though it is not so certain because of lack of fossils. It seems possible that the basal portion, which is developed only on the northeast, may represent a flood plain deposit under conditions of climatic aridity. The red color and the undecayed char-

acter of the feldspar grains in this portion may perhaps be thus explained.[1]

Above the basal division the rock becomes a purely quartzose one, and the red color disappears. This middle portion of the formation, as shown in Clinton county, becomes however its base to the west and south, because of the gradual encroachment of the subsidence in those directions, explaining the lack of arkose in St Lawrence county and in the Mohawk valley. Because of the occurrence, in St Lawrence county, of a quite pure, quartz sandstone resting on an uneven surface of crystalline rocks, Smyth has argued for a humid climate with rapid weathering at the time; and that, owing to the resistant character of the underlying rocks, the waves did not act for a sufficiently long time at a given level to plane away the rock floor to an even surface, though the time was sufficiently long to weather and triturate all minerals save the extra resistants quartz.[2] The writer quite agrees that a change in climate is probably indicated by the change in the rock character.

The offshore mud deposits of Potsdam time are nowhere exposed to view about the region. Some slight deposit of limestone took place, as shown by Walcott for the district about Saratoga, and by the well records published by Orton for the Oswego county region. The formation tends often to become somewhat calcareous or rather dolomitic, above, and everywhere grades into the overlying Beekmantown through a series of passage beds, which show rapid alternations of the two sets of contrasting conditions, the one gradually overcoming the other, so that subsidence must have been progressive, and no great time interval could have elapsed between the two deposits.

The bulk of the Beekmantown formation is composed of sandy dolomites, all very barren of fossils. They seem to the writer to indicate shore conditions and to a considerable extent "salt pan" conditions.[3] With the oncoming of Beekmantown time subsidence

[1]The writer has long been of the opinion that the early Potsdam climate was an arid one; and recent correspondence with Mr van Ingen has disclosed that he is also disposed to hold a similar view and is investigating the matter with the development of new and interesting evidence.

[2]N. Y. State Geol. 19th Rep't 1899, p.r100–2.

[3]Dana, J. D. Man. of Geol. ed. 4, p.133.

commenced on all sides of the Adirondack region; but, as was the case also in the Potsdam, it was most pronounced on the northeast and diminished in amount toward the west and south. The formation must have encroached on the Adirondack island on all sides, greatly diminishing its previous area. On the south side specially a large transgression of the sea on the former land took place, since the Potsdam shore line had been an unknown distance to the south of the present line of the Mohawk valley, while the Beekmantown has a thickness of from 300 feet to 500 feet there, and its shore must have lain several miles to the northward. On the west side of the region but little subsidence took place, and the Beekmantown shore line lay to the west of the present Precambric border there. In the Champlain region the formation has treble the thickness that it has along the Mohawk, and the transgression of the sea on the northeastern portion of the region must have been of vast extent. The Adirondack land mass must certainly have been an island during the Beekmantown, whose area was small compared with the present size of the region, and which lay mainly in its western portion, extending eastward for an unknown distance, greatest on the south side.

Then conditions changed, and the downward movement was replaced by an upward one, which caused cessation of deposition on the south and west sides of the area, brought a large but unknown amount of the previously submerged tract above sea level, so that the Beekmantown island was greatly extended in those directions, and shut off communication between the basin on the southwest and that on the northeast. The latter district did not feel the upward influence, but continued to subside, and the limestones and dolomites of the Cassin formation were deposited on the normal Beekmantown. The abundant fauna found fossil in these beds and absent from the Beekmantown beneath, must have entered the basin from the east or north, arguing for extended depression and open sea connection in one or the other, or both, directions.

The depression on the northeast persisted throughout Chazy time, though likely with interruptions, of which the most important is indicated by the basal sandstone of the Chazy. Like the preceding Cassin subsidence, this diminished rapidly in amount

southward, so that the rocks disappear through thinning at the upper end of the Champlain valley, the middle division of the formation being the last to vanish. Following the deposit of the upper beds, uplift ensued, or at least a cessation of subsidence and of deposit; there is little or no indication of wear at the Chazy summit, so that the surface could not have been raised much, if any, above sea level.

The large amount of subsidence on the northeast during Potsdam, Beekmantown and Chazy times must have involved that entire section of the present Adirondack region, since the Precambric floor of the district was not vastly irregular, nor could its seaward inclination have been great. The amount of rock thickness of these three formations which was deposited in the lower Champlain valley was from 3500 feet to 4500 feet, so that the upper Chazy deposits must have been carried far into the present heart of the Adirondacks by their overlap on the old land slope.

During Chazy times the Cassin elevation on the south and west sides of the region persisted, and no deposits of Chazy age were formed. The land was in fact sufficiently elevated to permit a certain amount of erosion of the Beekmantown deposits which formed its surface. The uplift was accomplished without tilting or folding of the rocks, except in a very minor degree, and in general the Lowville rocks appear to overlie the Beekmantown conformably. In some sections, as at Canajoharie, there is a plain discordance in dip between the two formations, owing to a very slight folding of the Beekmantown [pl.7]; but in most places nothing of the sort can be made out, though a comparison of several sections usually suffices to show that the Lowville does not always rest on the same bed of the Beekmantown. The surface was planed down to great evenness, arguing for either a long continued period of wear or else for a very low altitude and gentle surface slope.

The uplift of the northeastern region at the close of the Chazy was coincident with, or somewhat closely followed by, a movement of downward character on the south and west, which much diminished the land area there, bringing the shore line in close to the present Precambric margin of the region. The

Lowville limestone was deposited in these waters. The movement of the region was apparently pivotal, along a northwest and southeast axis which crossed at the upper end of the Champlain valley, sinking on the one side being accompanied by rise on the other. In that district this line formed the southern shore line of the Chazy sea and also the northern shore line of the Lowville sea. The thinness and the intermittent character of the Lowville formation, along the present line of the Mohawk valley, would indicate either that the Lowville shore line was not far away to the north, and that the subsidence was only trifling, or else that, after the deposition of the material, an uplift occurred and considerable wear took place. So far as the slender evidence goes, the former would seem to have been the case, since the unconformity at the base of the Lowville is much more pronounced than that at its summit, in fact there is little sign of wear at the latter horizon; while the not infrequent occurrence of alternating Lowville and Black River conditions would seem to bind the two formations rather closely together. It is therefore thought probable that the Lowville sea extended but little north of the Mohawk line and hence encroached little or not at all on the Adirondack region from the south.

On the west side of the region the formation has much increased thickness and apparently for many miles rests directly on the old, Precambric floor. Its thickness would argue that it must formerly have extended in several miles over the western Adirondack border, and farther than any of the preceding seas had done.

During Lowville time therefore the bulk of the Adirondack region was a land area, with wide extent to the north and east beyond the present boundaries of the district, with its southern shore line rudely corresponding to the present Precambric border on that side, and its western edge alone somewhat submerged.

The Black River limestone follows the Lowville on the south and west, with no sign of a structural break between the two. In the Mohawk valley the formation is thin and sometimes absent. In some cases its nonappearance is definitely due to the fact that the Lowville deposits had not completely filled the slight depressions in the Beekmantown floor on which they were laid down,

and the added thickness of the Black River was also insufficient completely to fill them. In these instances it seems clear that the slight elevations on which no deposit took place must have existed as shoals, and that hence the water was very shallow, and the shore line close at hand, as seems to have also been the case during the Lowville. There are sections, as in the Moore quarry at Pattersonville, measured by Prosser, in which the Black River rests directly on the Beekmantown, though the Lowville occurs thinly at its proper horizon, no great distance away, and such a section is demonstrative of uneven surface. On the other hand, the writer's work in the Little Falls region has shown that the Black River there has a very patchy distribution, and that about Middleville it is definitely absent, though the Lowville occurs there in considerable strength, and this is thought to point to an unconformity between the Black River and Trenton, the Black River being absent because of uplift and wear, after its deposition and before the beginning of the Trenton. Not unlikely the strong unconformity at Canajoharie is in part due to wear of this date, and not all to be ascribed to the period of Postbeekmantown erosion. This uplift seems to have been localized here at the southeast, since only there is the Black River found to be lacking. In the Mohawk region then, the shore line was close at hand and was irregular, though not so much so as at the commencement of the Lowville, and the one formation followed the other with no sign of a break, the two deposits combined nearly, but not quite, filling up the depressions; thence ensued an uplift about Little Falls, which brought about removal of the Black River through wear and caused the Trenton there to rest on the Lowville.

With the oncoming of Black River time, rapid subsidence seems to have been initiated on the east side of the region, the Chazy basin becoming again submerged; and the deposits thus laid down must have encroached as widely into the heart of the Adirondacks as the previous Chazy deposits had done. On the west side of the region also the formation is everywhere present, and thicker than on the south, so that the Black River sea was continuous around the region, and must have widely submerged it. There must have remained unsubmerged, however, an island of con-

siderable size, occupying approximately the same position as the previous Beekmantown island, but with considerably diminished area, specially on the western side. As in that case, this land was massed on the south and west.

The only stratigraphic evidence of a break between the Black River and Trenton, seems to be in the upper Mohawk region, where there is certainly a slight unconformity, with locally entire removal of the Black River. In Trenton times also the Mohawk region was but slightly submerged, and the formation is but thinly developed. This would argue some shore line near at hand, and Kemp's study of the Paleozoic outlier at Hope demonstrates the presence of land near the southern Adirondack margin, during at least the early Trenton.[1] In addition, it seems to the writer that this outlier presents suggestive evidence of the truth of the arguments advanced in the preceding pages, regarding the small extent of the invasion of the southern Adirondacks by the successive seas. In this outlier Potsdam, Beekmantown, Trenton and Utica strata are all present, and, with the possible exception of the last, none of them seem to have been deposited in great thickness, though during intervening periods of wear some thickness of each may well have been removed. Apparently the deposits indicate the near vicinity of a shore line to the north in Potsdam, Beekmantown and early Trenton times, and their thinness and character are due to such proximity.

Throughout most of the Mohawk valley region the Trenton has no great thickness, indicating but slight subsidence during its deposition. On the east and west sides of the region, however, it attains large thickness, hence subsidence was in progress on all sides of the district, and the encroachment of the sea over it must have considerably exceeded in extent even that of the previous Black River sea. The Black River island must have been nearly, if not utterly, wiped out by the close of the Trenton.

Then came in the muds of the Utica, appearing first on the east side of the region and gradually encroaching westward. Ruedemann's argument for the extension of the Utica over the entire Adirondack region, based on the parallel alinement of the graptolite fronds found fossil in the shales, as indicative of a uniform,

[1]18th An. Rep't State Geol. 1898. p.145–52.

unopposed current, seems to the writer to be conclusive.[1] The argument based on the thickness of sediments about the Adirondacks, and their necessary wide overlapping on the gentle slopes of the Precambric old land, also seems conclusive as to complete submergence during the Utica, the thickness and the evidence of gentle land slope being ample to warrant the conclusion. If any land remained during the Utica, it could have consisted of nothing more than a few, low, insignificant islands, and such must have been along the southern margin of the region. The slight amount of Trenton submergence in the lower Mohawk region may well indicate that, during a portion of Trenton time, there existed here a shoal barrier between the eastern and western basins.

The Utica was brought to a close by the shallowing of the waters, which may well have brought a considerable part of the Adirondacks, specially on the north, above sea level, though this is mainly conjectural. During Lorraine time, which followed, a shoal was developed in the region about Utica, probably extending thence northeastward, which separated the eastern and western waters. This would seem definitely to imply the emergence of land to the northward, and likely by the close of the Lorraine a large part, if not the whole of the Adirondacks, was elevated above sea level. The following Medina, Clinton and Salina waters washed the western and southwestern sides of the region only and may well have somewhat encroached on its margins. Then came elevation on the west, and the Helderberg depression on the east, the latter probably involving the eastern border of the district. The succeeding Devonic deposits may have reached the southern rim of the area, but could hardly have invaded it to any considerable extent.

Paleozoic igneous rocks. On both the eastern and southern margins of the Adirondack region, the Paleozoic rocks which fringe it are found to be cut by igneous rocks, mainly in the dike form. In the Champlain region these rocks cut, and are therefore younger than, the Utica shale, the youngest of the Paleozoic rocks to be found in the district. In the upper Mohawk district the dikes also cut the Utica shale.

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[1] Am. Geol., June 1897 and February 1898, p.75.

The Champlain eruptives of this period have received detailed description from Kemp.[1] They are more abundant in Vermont than on the New York side of the lake, and on that side seem mostly confined to Essex county, and to the near vicinity of the lake shore. They extend into Clinton county however, in which six small dikes belonging to this group have been found, are still more abundant in northern Vermont and extend thence northward into Canada. The Adirondack region seems to have been on the outer border of the region affected by the igneous activity.

Two contrasted groups of rock are present, the one light colored and acid, the other black and basic. The former are classed as bostonites by Kemp, the latter as camptonites, monchiquites or fourchites, according to their mineralogic character. As in the case of the older, Precambric dikes, the acid rocks seem less numerous than the basic and with a more restricted distribution, though these differences are in much less noticeable degree than in the earlier case.

Trachytes (bostonites). In New York State rocks of this group seem confined to Essex county, at least none have been discovered elsewhere. Kemp describes them as of prevailing light color, creamy or brownish white usually, but sometimes a light chocolate; of rough and granular feel and a fracture like that of trachyte. Phenocrysts are not numerous in general and are nearly always of feldspar, quartz having been noted but rarely. The ground-mass is constituted of minute feldspar laths with usually well marked flow structure. Between the laths small particles of interstitial quartz are sometimes to be detected. The feldspar is both orthoclase and anorthoclase, little or no plagioclase being present. A considerable amount of hematite is present in minute, disseminated scales, but aside from the above no certain primary minerals can be made out. Calcite, quartz, kaolin and limonite are the principal materials resulting from alteration, and in general the rocks seem hardly as fresh as the older syenite porphyries of Clinton county, which they much resemble.

At Cannons point, just north of Split rock, Kemp has described a large mass of this rock as a sheet, or laccolite, the exposures

[1] U. S. Geol. Sur. Bul. 107.

apparently not being sufficiently extensive to permit of certainty in the matter. This is the only known instance in New York where any of these rocks occur in other than the dike form.

Basic dikes (*camptonites, monchiquites and fourchites*). Of these basaltic rocks the main mineralogic constituents are a basic feldspar, usually andesin or labradorite, augite, brown hornblende, olivin and biotite. The camptonites are feldspar augite, or feldspar hornblende rocks; in the monchiquites and fourchites the feldspar retreats or disappears, thus separating them from the camptonites, and they are distinguished from each other by the presence in the former rock, or the absence in the latter, of olivin. Some glassy base is usually present, specially in the latter two rocks, and they not infrequently contain analcite.

Camptonites are mostly characterized by the presence of brown, basaltic hornblende in sharply bounded crystals. It is often more or less replaced by augite, up to complete disappearance of the hornblende. Such rocks differ but little from diabases, the difference being a minor, structural one; in the diabases the augite formed somewhat later than the feldspar and accommodated itself to the feldspar outlines, instead of presenting its own outlines; in the camptonites it formed earlier and is more apt to have its normal outlines. In most cases at least some brown hornblende is present, and serves to distinguish the two rocks. In many of the dikes there is no augite whatever. Magnetite is the only other mineral uniformly present. Some little glassy base is apt to be at hand also.

The monchiquites consist of olivin, augite, hornblende, biotite (one or all three of the last named), and a glassy base. Like the camptonites these are apt to be porphyritic. Analcite is not infrequently present. The fourchites are similar except for the lack of olivin, and consist principally of augite, though with some hornblende or biotite. They are much rarer than the monchiquites in the Champlain district. A related rock, ouachitite, in which the biotite predominates and augite retreats, has not been so far noted in the district, though biotite is abundant in several of the dikes.

Age of the Champlain dikes. Kemp was the first to note that these acid and basic dikes of the Champlain region are of the

sort which usually accompany nephelin syenite igneous bodies, but that such are absent in the immediate region, though occurring in Canada to the northward, and to the eastward in New England. It is of course possible that masses of the sort are present in the Champlain region but are as yet uncovered by erosion. It would seem however that these Champlain dikes are on the southeast margin of a considerable region which was affected by the igneous action, and that evidence regarding their age may be sought in the entire affected area. In the immediate Champlain region no closer determination of their age can be made than that they are younger than the Utica shale, which some of them cut. There would seem to be no question that they are older than the Trias, or are of Paleozoic age, since the igneous rocks of the Trias are of quite different sort, and rocks like these are nowhere found associated with them. The evidence given by the exposures on St Helen's island, near Montreal would indicate that these rocks are at least as young as the early Devonic; and the writer has recently come to the belief that a Carboniferous age must be assigned to them, though this is not possible of demonstration at the present time.

Chemical analyses. No very good and complete analyses of these Champlain eruptives have yet been made, though they closely conform to similar rocks elsewhere. Such as are available are given by Kemp in United States Geological Survey, bul. 107. It is however of interest to note their quite striking similarity in composition to the earlier dikes, which preceded them in late Precambric time. The camptonites and monchiquites are chemically very close to the earlier diabases, and an equally strong resemblance obtains between the bostonites and the syenite porphyries.

Igneous rocks of the upper Mohawk region. Smyth, G. H. Williams, Darton and Kemp have described very basic rocks, of the peridotite class, about Manheim. Syracuse and Ithaca.[1] These rocks are only remotely connected with the Adirondack region, but completeness would seem to make desirable some considera-

[1]Darton & Kemp, Am. Jour. Sci. June 1895, p.456–62; Kemp, J. F. Am. Jour. Sci. Nov. 1891, p.410–12; Smyth, C. H. Am. Jour. Sci. Ap. 1892, p.322–27: —— Am. Jour. Sci. Aug. 1893, p.104–7; Geol. Soc. Am. Bul. 9: 257–68; Williams, G. H. Am. Jour. Sci. Aug. 1887, p.137–45.

tion of them. They occur for the most part in very irregular dikes, often of very small width. They belong to the peridotite class of igneous rocks, the most basic of any. Such rocks are prone to rapid decay, and these are no exception, all of the known exposures being considerably, and many of them highly altered and rotted.

In general their mineralogic make-up is of biotite, olivin, pyroxene and melilite, with accessory magnetite, perovskite and apatite. Wherever sufficiently fresh material has been forthcoming, the presence of melilite has been noted, Smyth having early shown its presence in the Manheim rock and having recently detected it in some new material from the Syracuse vicinity. Alnoite is the name applied to a melilite holding peridotite. All the rock contains biotite and olivin in quantity, but the pyroxene is much more irregular in its occurrence. It is rare or else absent in the Manheim rock; while Kemp has shown that it is the main mineral of the ground-mass in the Dewitt dike near Syracuse. Likely some glassy base was present in nearly all occurrences. In all except the freshest rocks the olivin has gone to serpentine, and Smyth has described in detail the processes of alteration and decay.

Chemical analyses. Since these rocks are all considerably altered, analyses of them are not trustworthy if what is sought is the actual composition of the fresh rock. Yet, if the analyses are made from the freshest possible material they will give good evidence of the general character of the igneous magma, and of the closeness of correspondence of the rocks from the separate occurrences.

	1	2	3	4
SiO_2	36.8	33.8	35.25	37.44
Al_2O_3	4.16	6.84	6.1	28.6
Fe_2O_3	n. d.	12.26	8.53	11.92
FeO	8.33	n. d.	5.6	n. d.
MgO	25.98	21.38	20.4	1.97
CaO	8.63	9.5	7.4	5.45
Na_2O	.17	n. d.	.7	.97
K_2O	2.48	n. d.	2.88	1.02
Loss[1]	12.25	15.2	12.4	12.67
Sum	100.27	98.98	99.26	100.04

[1] In no. 1 includes H_2O+ 6.93, H_2O- .51, CO_2 2.95, TiO_2 1.26, P_2O_5 .47, MnO .13; in no. 3 includes TiO_2 2.25.

1 Dewitt dike near Syracuse. Darton & Kemp, *op. cit.* p.461, analyst, H. N. Stokes.

2 Manheim, Herkimer co., C. H. Smyth, *op. cit.* p.325, analyst Smyth.

3 Manheim, Herkimer co., C. H. Smyth, *op. cit.* p.262, analyst Smyth.

4 Ithaca, J. F. Kemp, *op. cit.* p.412, analyst W. H. Morrison; analysis incomplete, and the alumina and magnesia determinations obviously incorrect.

The first three of these analyses are of *fairly* fresh material, when the character of the rock is taken into consideration. They suffice to bring out clearly the close relationships of the rocks from the different localities, as evinced by the low silica and alumina and the very high magnesia. While these characters belong to the general rock group to which these rocks pertain, they are the only igneous rocks of the group known in the State, and therefore clearly represent outflows from the same subterranean source. So far as known, they are confined to the central part of the State, but the three localities are so widely separated that unquestionably others will be forthcoming.

ROCK STRUCTURES

The rocks of the Adirondack region may be separated into three main groups of widely separated age, owing to the fact that there have been three main periods of rock formation in the region, separated by protracted intervals of wear. The Precambric rocks constitute the first group, the early paleozoics the second, and the pleistocene deposits the third. The last are so recent as to be in substantially the condition in which they were deposited, unconsolidated masses of glacial deposits and of marine and fresh-water sands and clays. A vast time interval separates them from the paleozoics, which are all thoroughly indurated rocks, but which are otherwise not greatly altered from their original condition, though they have suffered somewhat from earth stresses and movements. Another vast time interval separates these from the Precambric rocks, and the latter underwent profound changes in character during this interval. They therefore present structural features which are confined to them, as well as others which they share with the Paleozoic rocks.

Foliation

In the Adirondack region the Precambric rocks alone have suffered metamorphism, but they are so profoundly metamorphosed, the late dikes always excepted, as to have been vastly

altered in character. The change consists, for the most part, in a recrystallization of their constituent particles, destroying their original textures and structures and developing new ones. The Grenville and Saranac rocks are the ones most affected and in large part have their original characters utterly destroyed. In the great igneous masses the changes are not so widespread and profound, so that often there is at least a partial preservation of their original characteristics.

The old sedimentary rocks have lost all traces of lamination and nearly all signs of original bedding; they have undergone complete recrystallization, entirely obliterating their old textures, and, as a result of severe compression, have had a development of cleavable minerals along certain parallel planes, the mineral particles having a common orientation. This gives rise, on the part of the rock, to a capacity to split along such planes, and the structure is a variety of cleavage, and is known as foliation. Sometimes this new structure is parallel to the old bedding planes and sometimes it is not; often the latter can not be made out at all. In general the old limestones, now converted into coarse marbles, are the only sedimentary rocks which are not now foliated. This is because of the facility with which such rocks become crystalline, their rather uniform composition, such that they consist mainly of one mineral, and their comparatively great plasticity under pressure.

The great igneous masses are, in general, much less foliated, though this is not true of many of the smaller ones, and specially not of the older ones, those that seem to be of Grenville age. In considerable part the absence of foliation in much of the igneous rock is thought to be due, as in the limestones, to the fact that the rock is largely constituted of a single mineral. Much of the anorthosite, and to a lesser degree of the syenite also, is quite purely feldspathic, the minerals which are most effective in producing foliation being present in but slight quantity, or not at all. Such rocks are often badly mashed and granulated, indicative of the great pressures which they have experienced, but with no production of foliation. But, with change in the rock composition, with the formation in quantity of biotite, amphibole or pyroxene, more or less foliation is pretty sure to be induced in

the rock. In all the large igneous masses, the general more basic character of their peripheral portions has resulted in the formation of such minerals there, hence their tendency to pass over into gneisses at their borders, a tendency so widespread as to be practically universal. The gabbros of the region possess throughout a large proportion of such minerals, and in the writer's experience they, though the youngest of the igneous rocks of the group, are much more uniformly gneissoid than are any of the others. True, comparatively unchanged cores remain in nearly every case, so that the original character of the rock may be demonstrated, but this is usually of small bulk in comparison with the hornblende gneiss, produced from it by metamorphism.

In many of the granites also there is a great scarcity of the foliation-producing minerals, the rock being mainly, or wholly, constituted of quartz and alkali feldspars. These rocks are apt to lack foliation, and then not infrequently have a somewhat similar linear structure, the quartzes being drawn out into spindles and pencils, with a direction corresponding to the foliation direction of the inclosing rocks. A similar tendency may often be noted in the more quartzose syenites. This structure has only been noted in these quartzose rocks, hence a natural tendency to attribute it to the mineral composition. But coupled with that may well have been such slight differences in the mean and maximum pressures in the rock that it suffered nearly equal shortening in two directions at right angles, and elongation merely in the third.[1]

The foliation in the Precambric sediments seems, in general, to be parallel to the bedding, so far as the latter may be made out. Over the greater part of the district the dips are comparatively steep, ranging in general from 20° upward. Judging from the writer's own experience, and from the published data of other observers, the strike is seldom uniform over any considerable area, but is now to the northeast, now to the northwest. North and south, or east and west directions are much more infrequent. The shifting of the strike direction indicates that we are dealing with folded rocks, and that this is actually the case is readily demonstrated in the Grenville sediments, but with difficulty elsewhere. It is also evident that the folds

[1]Hoskins, L. M. U. S. Geol. Sur. 16th An. Rep't, p.870.

have a considerable pitch, and the writer's impression is that in the northern part of the region at least, the pitch is to the north. The major folds would seem to be broad and not excessively steep, but their limbs are corrugated by minor folds also, and it is in these that the steepest dips are obtained.

The great igneous batholites of the Adirondacks are massed in the east center of the region. Going west and south, a zone is passed through marked by increase in Grenville sediments and diminution of igneous rocks. On the west and south the sediments largely predominate. It is in these areas that the folds must be worked out, provided they can be worked out at all. If so, the knowledge thus obtained may be, perhaps, successfully applied to the elucidation of the structure of the more difficult interior area, more difficult because of the much larger content of poorly foliated igneous rocks. The writer's work has been mainly in the latter district. It ought to be possible with good maps and careful areal work, to make out the axes of at least the larger folds. The folding was certainly done in Precambric times and while the rocks were buried at some considerable depth; hence it long preceded the period of diabase eruption, and these dikes are wholly unaffected by it.

Folds

Aside from the folding of the Precambric rocks, just noted, which was produced in Precambric times, the rocks of the region are but slightly folded. Along Lake Champlain the Paleozoic rocks are thrown into a series of very gentle folds, which have subsequently been so much faulted that the folding is not always apparent. Across the lake in Vermont the folds become rapidly more pronounced, but on the New York side only a trifling amount of folding has taken place. The dips are in general very low, and in many cases so flat that they are made out only with great difficulty. They are almost always below 10° and usually below 5°. In the few instances where they are steeper, the cause is usually found to be the tilting of a small fault block, or drag in the vicinity of a fault. A steep dip may usually be taken as an indication of proximity to a fault. However, the rocks are unquestionably slightly folded, marking in all probability merely the waning effects of the force

which produced the greater folds to the eastward. So far as observed, the folds trend nearly north and south. Minor folding, of sometimes considerable amount, is often observed in the near vicinity of faults, and in many cases at least is a result of the faulting, being apparently due to differential movement along the fault plane.[1] Such folds are small and rapidly die out with recession from the fault plane.

Westward, along both the north and the south sides of the region, evidence of folding is progressively less evident. That there are low undulations of the strata can not be doubted, but such are found in nearly all districts, of even the least disturbed rocks, and can be located only with the most painstaking care, if at all. Slight local folds, sags is a better term, are not uncommon in the limestones of the Mohawk valley, but seem to be local and not regional structures.

Faults

Precambric faulting. The location and tracing out of faults in the Adirondack Precambric is an exceedingly difficult task, and, in so far as they have been located, their recognition has depended more on topographic than on structural evidence. The discrimination between Precambric and later faulting is trebly difficult, and for the most part has not been attempted. Practically all topographic indications of Precambric faults must have been obliterated during the protracted period of Prepotsdam wear on the then land surface of the region. At the present day large faults of the sort could be most readily detected at the Precambric margin, by showing that the overlying sediments had not been affected by the process. No such evidence has yet been forthcoming so far as the writer is aware. Yet there does seem to be evidence of at least some Precambric faulting.

In the eastern Adirondacks, where diabase dikes abound, it is a frequent experience to find them faulted. Often the same dike will be faulted more than once within comparatively small distance. The recognizable faults of this sort are usually of very

[1]Folds of this sort are shown on most of Brainard and Seeley's excellent sketch maps of bits of the Champlain region. See for example Am. Mus. Nat. Hist. Bul. 8:309–11, and Am. Geol., November 1888, p.326.

small throw, or at least of small heave, the dikes being shifted laterally a few inches, or a few feet. More rarely the fault is of sufficient dimension to cause the disappearance of the dike on one side, its new position being beyond the limits of the outcrop.

Since these dikes are themselves of late Precambric age, the fact that they are faulted would indicate a very late Precambric age for the faulting, provided it is Precambric at all. The only evidence of such age is the fact that the later faults, so far as they have been made out, are less numerous and of larger throw. While this is suggestive, it is but slender evidence for making such a discrimination.

As will shortly be shown, joints abound in the Precambric rocks. In numerous instances evidence of vertical slipping along these joints is forthcoming, the immediate rocks being much crushed and sheared, and the planes of slip thoroughly slickensided. Excellent illustrations may be found in the numerous rock cuts along the railroad between Saranac Inn and Floodwood, in Franklin county. The anorthosite is seen to be locally much shattered, abundant joints dividing it into parallel sheets of a thickness of from 2 inches to 4 inches, the rock material much crushed and sheared and the sheets slickensided on both surfaces. The whole zone so affected varies from a few feet to a few yards in breadth, grading off into the normal rock. The frequency of the phenomenon in these excellent exposures suggests that it can hardly be local, and that the fact that it has not been more widely noted may likely be owing to the general poor and unsatisfactory character of the usual exposures in the woods. That, in other words, it is a common occurrence.

Here again the evidence that the faulting may be of Precambric age is merely the difference in character. The Paleozoic faults are fewer and of large throw, and so far as noted do not consist of numerous small slips along closely recurring joint planes, with the production of a multitude of slickensided surfaces. Here again the evidence is far from conclusive. There is however a system of joints in the Precambric rocks which antedates the Paleozoic, since there are more joint systems in the former than in the latter rocks. If it could be demonstrated that the system of joints along which this faulting took place was

Plate 11

Faulted granite dike, near Westminster park, Wells island

formed in Precambric times, the case for the age of the faults would be made out, but this has not yet been successfully done.

Kemp has described three diabase dikes cutting the ore body in the Hammondville iron mines, which he says fault the ore, raising it about 15 feet in each case.[1] The dikes appear not to be faulted. If this be true, the faulting could hardly have been later than the time of dike extrusion. A later fault might, it is true, have paralleled the dike, but that this was the case ought to be readily made out in the exposure. This would seem therefore to be a veritable instance of Precambric faulting.

The older Precambric dikes of the region, more specially the granite and pegmatite veins, are not infrequently found faulted repeatedly and in small amounts, as the diabase dikes are [pl. 11]. Precise evidence of the date of faulting is equally lacking here.

On the whole then it is to be said that, while demonstrative evidence of Precambric faulting to any special extent has not been forthcoming, it is nevertheless quite probable that such was the case, the faulting having occurred in rather late Precambric time, when, owing to the long continued surface erosion, the originally deeply buried rocks had been transferred from the deeper zone of flow to the superficial zone of fracture.

Paleozoic faults. As such may be classed in all probability all faults found in the Paleozoic rocks and many of those in the Precambric. Faulting may well have been initiated in the region at the time of the uplift which terminated Lower Siluric deposition, and which was most marked on the east, being there accompanied by some considerable disturbance of the rocks. The great earth disturbances which prevailed in the Appalachian zone toward the close of the Paleozoic would seem more likely to have brought about the major faulting of the region. To the east and south of the district there was a time of disturbance, resulting in prolific faulting, in the Mesozoic; but, if the region in question was also affected, the results can not be discriminated from those produced in the Paleozoic. However, the Champlain and Mohawk faults are of a different type from those which abound in the Newark Mesozoic of New England and the Middle Atlantic states, which is evidence against their being classed together.

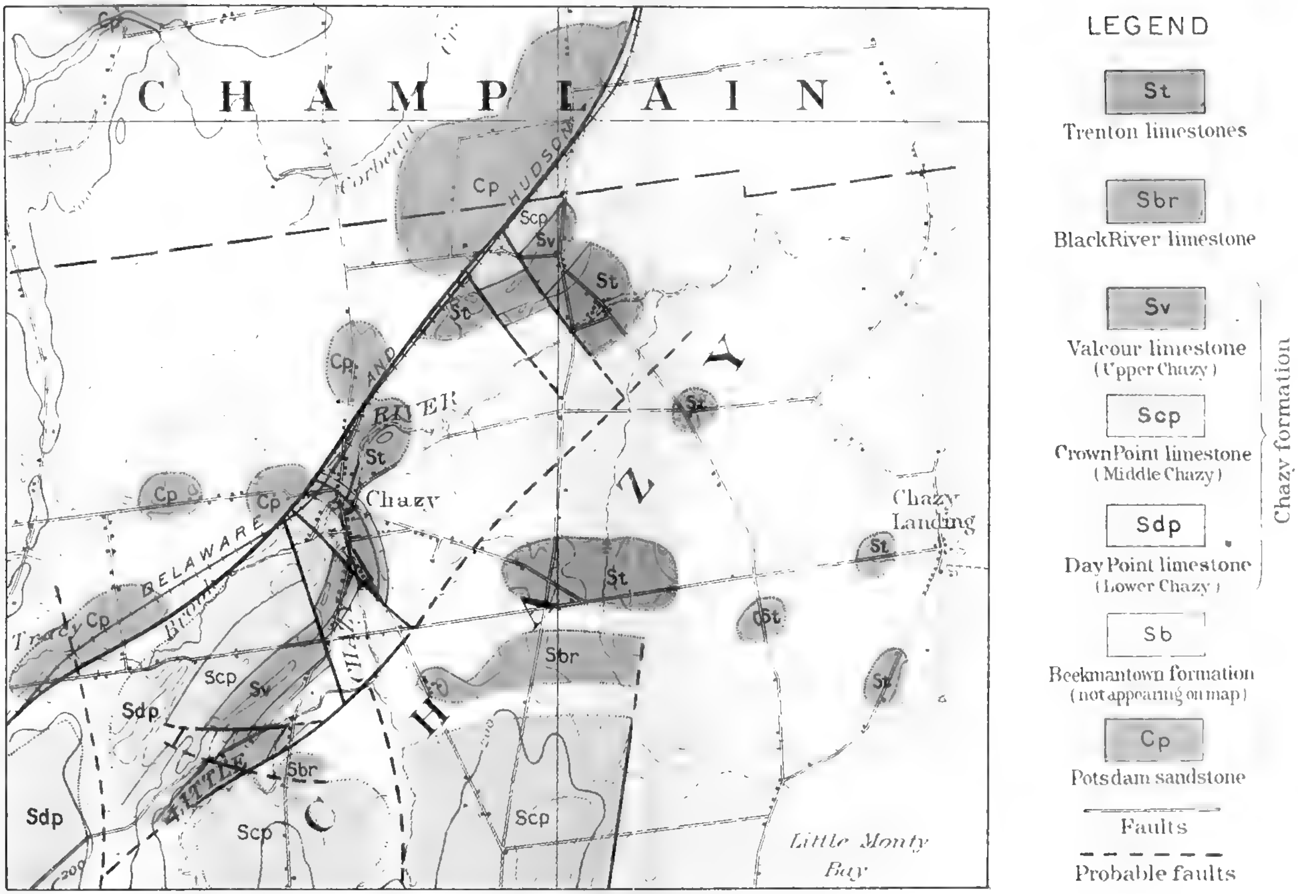
[1] U. S. Geol. Sur. Bul. 107, p.40.

In the eastern Adirondacks there is some evidence of yet more recent faulting, which may have utilized the already formed fault lines, or constructed new ones, the former seeming the more probable supposition, though it is in general impossible to say which was the case. So far as known to the writer, the evidence for this later faulting is topographic simply, certain prominent fault scarps being difficult of explanation except on this assumption.

These Paleozoic faults are for the most part readily made out in the marginal belts of Paleozoic rocks of the Champlain and Mohawk valleys. They are not so readily discoverable on the north, owing to the very low northward dip of the Potsdam and Beekmantown formations there, the great thickness of both these formations and the northerly slope of the surface in the same direction as the rock dip, giving them great breadth of outcrop; while their various beds are so similar lithologically and so unfossiliferous that precise horizons are not to be made out, in a district of such scanty outcrops. Enough evidence can be obtained however to show that the faults do occur, and that the conditions are quite like those on the south side of the region. The strong probability is that the faults, or rather the faulting, extend clear across the region. Evidence of their presence is frequently forthcoming in the Precambric areas, but in these it will require the closest sort of areal work to disclose and to map them accurately.

Faults most abound and attain greatest magnitude along the eastern border of the region. Thence westward they diminish in number and in importance, though large faults occur as far west as Little Falls in the Mohawk region, and at Potsdam on the north, and small ones, at least, are found still farther west.

The greater breaks of the region are meridional, trending from a north-south to a northeast-southwest direction. They therefore rudely parallel the strike of the Paleozoic rocks in the Champlain region, while in the Mohawk region, and on the north, they cut it at a high angle, forming what are known as dip faults, the others being called strike faults [fig. 3, 4]. The large majority of them downthrow to the east and with their rude parallelism divide the region into a series of strips, or slices, this slicing apparently characterizing the bulk of the Adirondack region.



OUTCROP MAP OF A PORTION OF THE TOWNS OF
CHAZY AND CHAMPLAIN, CLINTON COUNTY,
SHOWING THE FAULTS, SO FAR AS THEY HAVE BEEN LOCATED
by H. P. Cushing
1904.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 Miles

Contour Interval 20 feet

Datum is mean Sea level

In addition to these greater, meridional faults, differential slipping in the fault strips has resulted in the production of a multitude of cross faults, trending away from the greater ones at all angles, downthrowing now to one side and now to the other, and thus dividing the strips into a number, often a large number, of blocks of varying size and shape, producing great confusion in the stratigraphy and tending to disguise the larger features of the region. These are mostly a feature of the Champlain region and have not the persistence westward of the meridional breaks.[1] As a general rule, they have a somewhat east and west trend but with wide variation in direction. They downthrow now to the north and now to the south, with frequent production of small sunken blocks, downthrown on both the bordering faults. They are in general dip faults, shifting the rocks along the strike, while the large strike faults are apt to cause disappearance of a considerable part of the rock section of the district on the two sides of the fault [fig. 3, 4]. Thus along the great Tracy brook fault, in Chazy township, the entire Beekmantown formation is faulted out, bringing the Chazy and Potsdam together on opposite sides of the fault. A small portion of the course of this fault is shown on the accompanying map [pl. 12]. Just within the map limits its course is more nearly northeasterly than is usual with the great faults and more nearly so than is the case with most of the course of this special fault. About 1 mile to the southeast a parallel fault is seen, and the strip which intervenes between the two is intricately cut up by a number of cross faults, much more so than is true of the district adjoining the strip on either side. Along this pair of faults the entire Beekmantown formation, at least 1500 and likely 1800 feet in thickness, is faulted out, together with an unknown thickness of the Potsdam, from 100 feet to 300 feet at least, and a portion of the Chazy, so that the throw of the fault is 2000 feet or more. It is not a true strike fault, since the dips hereabout are swerving from an easterly, to a northeasterly or northerly direction, but they are so low that the general effect of disappearance of a certain thickness of strata from the

[1]The Mohawk valley faults and some of the larger Champlain faults are well shown on the large geologic maps of the State. The two large scale maps of portions of Clinton county [pl. 12, 13] better illustrate the general character of the faulting in the Champlain district.

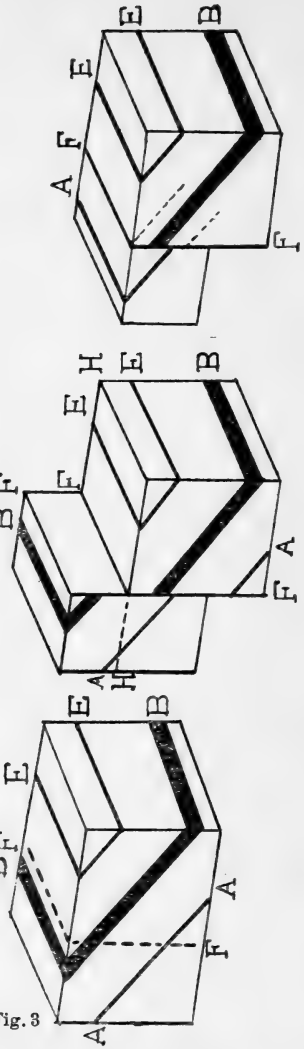


Fig. 3

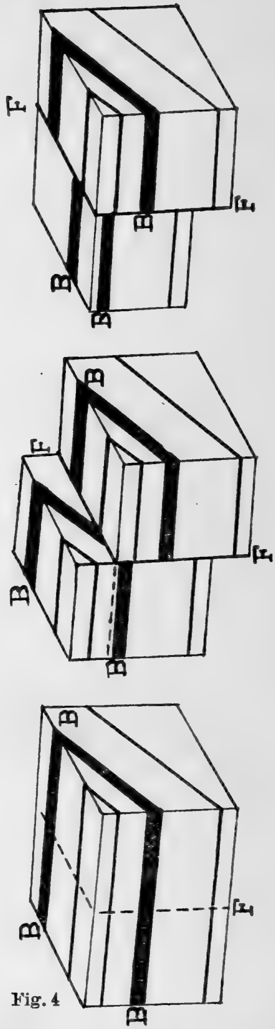


Fig. 4

Figure 3 illustrating a strike, and figure 4 a dip fault. FF is the fault plane, AA, BB, and EE indicate the dipping rock layers. In the former figure the fault plane cuts the surface parallel to the strike, causing a strike fault, in the latter the strike is cut at right angles, producing a dip fault. On the left the unfaulted block is shown, with the position of the fault dotted. In the center the conditions prevailing shortly after completion of the faulting are shown, the downthrow block on the right, and with the prominent fault scarp. On the right the conditions prevailing after sufficient time has elapsed for wearing away the upthrow block down to the level of the other side, or rather for wearing the two sides down to a uniform level, are indicated, this being approximately the condition of most of the faults of the region at the present time. In the strike fault this results in the entire disappearance from the surface of the stratum BB, in the vicinity of the fault, the actual thickness of rock so disappearing being comprised in the space between the dotted lines on either side of BB. By varying the amounts of hade and dip, or their directions, repetition of strata at the surface, instead of disappearance, may result. In the dip fault the effect is to shift the outcrop of a given stratum, so that in an old fault, the surface having been worn down, the ends are shifted forward or back, as the case may be, on opposite sides of the fault, as BB is shifted in the diagram. The amount of this shifting increases with increased throw of the fault, and diminishes with increased dip of the rocks. Few faults meet these conditions of correspondence with dip or strike direction exactly, but many make such slight angles with these directions that they are practically fulfilled.

OUTCROP MAP OF A PORTION OF THE TOWNS OF PLATTSBURG AND PERU, CLINTON COUNTY,
SHOWING THE FAULTS, SO FAR AS THEY HAVE BEEN LOCATED
by H P Cushing
1904

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

Contour Interval 20 feet

Datum is mean Sea level

surface is similar. The small fault blocks in the intervening strip have been updragged by the faulting, giving them a pronounced dip, in general 10° or more, away from the fault plane toward the southeast. Hence the faults that cross the strip are quite typical dip faults, and the lateral shifting of corresponding beds on the two sides of a fault is plainly brought out on the map. Owing to the steep dip, the more resistant rock layers involved appear as low, sharp backed ridges, and the lateral shifting of these, as a fault is crossed, is a prominent, minor feature of the topography. In the most northerly pair of these faults shown on the map, the north one throws to the north and the south one to the south, so that the middle block has been upthrown between the two others. Just the reverse is true with the pair just south of Chazy village, the middle block having been downthrown between the two adjoining blocks. On the east and west edges of the map faults are not indicated simply because outcrops are not sufficiently numerous, or sufficiently definite, to permit of their location. That they are there is quite certain.

Plate 13 shows the faults in a portion of Plattsburg and Peru townships, so far as the outcrops will admit their being located. One very extensive fault of the meridional class, the Plattsburg fault, runs across the map limits from north to south, exposing Beekmantown rocks constantly on the west side and either Chazy or Trenton on the other. The throw of the fault causes the disappearance of the major part of the Beekmantown formation and may be safely set down as at least 1000 feet. Toward the north the throw diminishes, and another great fault develops, the Beekmantown fault, the two coalescing at the north limits of the map and extending on beyond as a single fault of very large throw. Between the two a wedge of Chazy is brought up, with Beekmantown rocks on one side and high Trenton on the other. At the point of junction the Chazy is pinched out and the Beekmantown and Trenton rocks adjoin across the fault. There are two cross faults in this Chazy wedge, two on Valcour island, one on the mainland at Valcour and another just north of Bluff point, as well as several small ones in the shales on Cumberland head, and one on the south edge of the map at Lapham, which brings up the Potsdam against the Beekmantown. Lack of outcrops prevents the location of others.

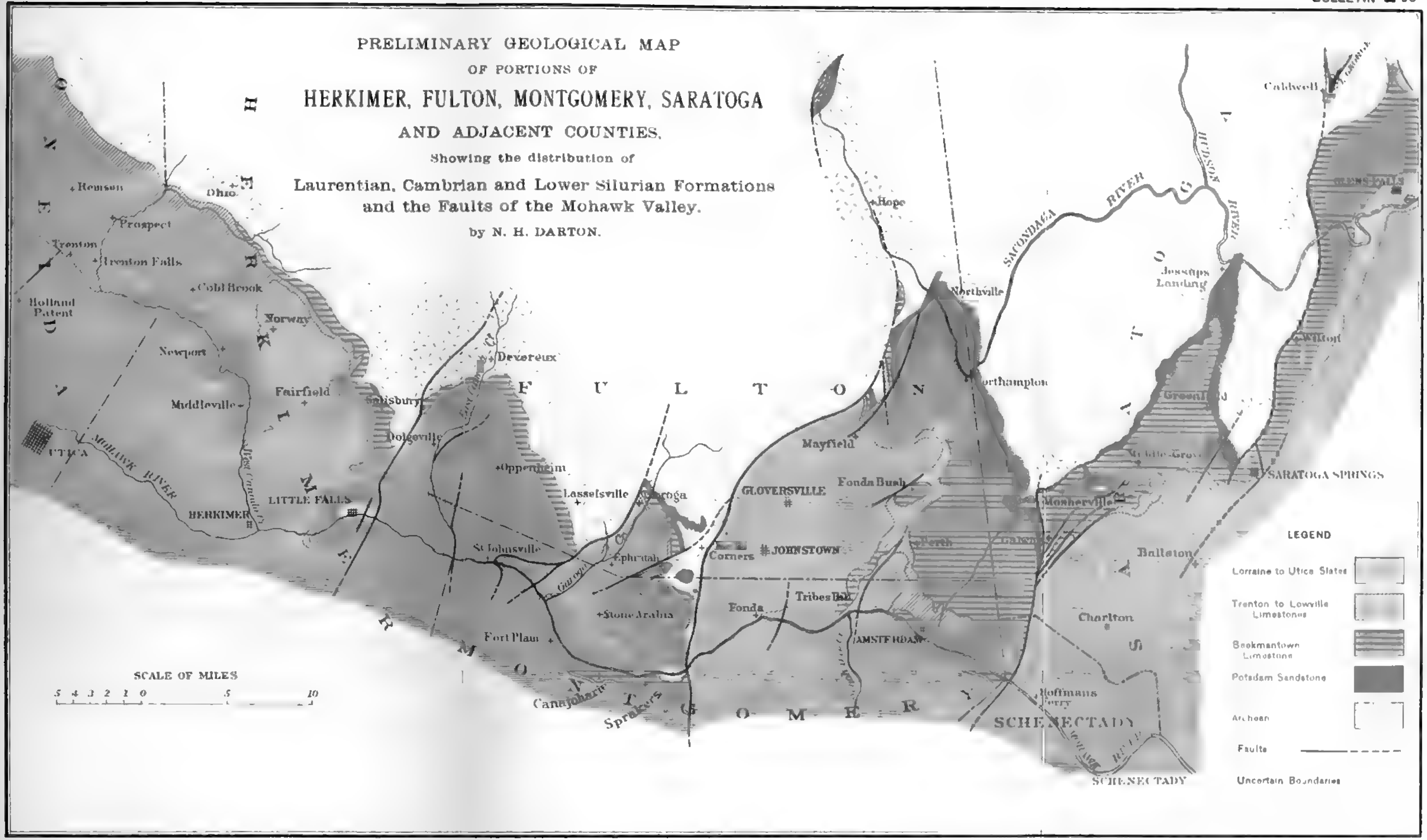
Such conditions everywhere characterize the country along Lake Champlain. Wherever any bit of it has been mapped in detail, one or more faults are sure to be disclosed. They constitute the most prominent and characteristic structural feature of the region.

The faults of the Mohawk valley have been most carefully studied and described by Darton.[1] They are inferior to the greater Champlain faults in number and in size, and the numerous cross faults which characterize that region are less manifest or are lacking here, the faults all having a north to northeast trend, with rude parallelism. Four large faults only, cross the Mohawk valley, the Hoffman, Noses, St Johnsville and Little Falls faults, [pl. 14] though there are several minor ones of less magnitude and extent. Others occur to the northeastward in the Saratoga region, and there must be still others which remain yet undiscovered.

None of these faults have been traced to any distance on the south side of the Mohawk valley, and it is not certain whether they disappear there, owing to dying out, whether they are there but are difficult to trace, owing to unfavorable conditions, or whether they apparently disappear because the overlying Upper Siluric and Devonic rocks were not affected by them. The matter is of importance as giving evidence of the date at which the faulting took place. So far no rocks younger than the Utica and Lorraine shales are known to be involved. If it could be shown that the younger rocks to the south of the valley were also affected, the probability of their Carboniferous age would be much strengthened, or at least any correlation of their date with that of the Taconic disturbance would be rendered impossible.

The only one of these great Mohawk faults with which the writer is on terms of intimacy is the Little Falls fault. With the remainder he has but passing acquaintance. According to Darton all are normal faults with nearly vertical hade, and all downthrow to the east, with the single exception of the comparatively small Dolgeville fault. The throw of the Little Falls fault, where it crosses the Mohawk, is not far from 800 feet, and it maintains approximately the same throw for several miles to the northward. The St Johnsville fault has branched and is fast diminishing in

[1] 14th An. Rep't State Geol. 1894. p.33–54.



Reprinted with slight change from 14 Rep. State Geologist, 1894.

throw near the river, but it increases rapidly northward, Utica shale on the east side adjoining Precambric rock on the other, so that the throw there would seem of equal magnitude with that of the Little Falls fault. The Noses fault involves the entire thickness of the Beekmantown and Trenton formations, the latter only 17 feet thick here, together with an unknown amount of the Utica. The two former aggregate 500 feet, so that a minimum value is thus given, to which must be added the thickness of Utica involved. According to Prosser the Hoffman fault throws out the entire Utica and Trenton and some of the Beekmantown, so that its throw is just about 1600 feet.[1] It is, then, the greatest of the Mohawk faults, as it is also the most easterly.

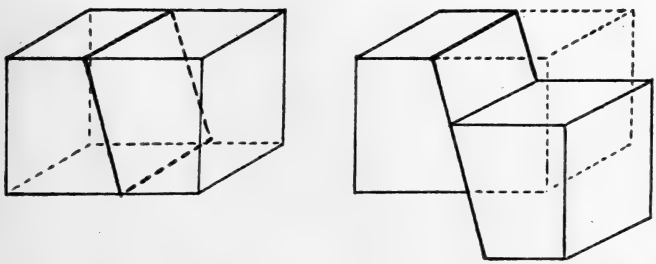


Fig. 5 To illustrate extension owing to normal faulting. First, the unfaulted block is shown with the position of the fault plane, second, the block after faulting, with the original position dotted. The lateral extension, or heave, is manifest. The hade of the fault is 15° and the lateral extension about one fourth of the vertical displacement.

This whole faulted district closely adjoins on the west the district of Appalachian folding. This is a region of sharply compressed rocks, producing folding and thrust faulting. The region under consideration was but slightly affected by these forces, thrust faults being absent and folds present only in the most minor degree. Normal faults are however abundant, in fact are present in both districts. But normal faulting implies surface tension instead of compression, since, except in cases where the hade is absolutely vertical, the rocks have greater lateral extent after the faulting than before [fig. 5]. Since absolutely vertical faults are exceptional, much normal faulting in a district of parallel faults must produce a respectable amount of surface extension. The period of tension would seem to have followed that

[1] N. Y. State Mus. Bul. 34, p.476.

of compression, as is apt to be the case, and this also argues for the late Paleozoic date of the faulting.

Joints

All the rocks of the region are cut by joints, but they are specially abundant in the Precambric rocks. Since joints can be formed only in the zone of fracture, their development in these rocks must have been long subsequent to the formation of folds and of foliation, during which interval the rocks had been approaching the surface because of wearing away of what was above. The joints which are found in the Precambric rocks and not in the overlying paleozoics must be of Precambric age.

Joints may be produced either by compression or by tension. Those of the latter sort are usually vertical or nearly so, while those of the former may be either vertical or inclined. The simplest case of tension jointing is the production of columnar joint cracks in igneous rocks owing to contraction on cooling. Some of the joints of the dikes of the region are of this class, it being the invariable experience that they are more excessively jointed than are the inclosing rocks. The solidifying and cooling of the great igneous masses of the region, however, took place at such great depths as to be below the zone of fracture, and hence they lack joints of this character, being neither more nor less jointed than are the neighboring gneisses.

Tension joints may also be produced by the desiccation of marine sediments underground, and this cause may have operated somewhat in the production of joints in the Paleozoic rocks, though it is doubtful.

Another very likely cause of the production of tension joints is the slow reduction of temperature brought about in rock masses as they approach the surface because of the slow removal by erosion of the overlying rocks. Though the process is an exceedingly slow one, and the changes of temperature involved are not large, yet, considering the great areal extent of the rocks concerned, the necessary contraction would seem considerable, and likely to much exceed the elastic limit of the rocks.

Where rocks are folded in a complex manner, as is usually the case, torsional effects are sure to be produced, which result in the production of two sets of joints, one running parallel to the axes of the major, and the other to the axes of the minor folds.

Compression of rocks in the zone of fracture may give rise to jointing which follows the shearing planes. There would be two different joint sets, which would cut the surface parallel to each other. Such joints would be inclined instead of vertical, the amount of inclination depending on how largely the shear was determined in direction by preexisting planes of weakness, such as bedding or foliation planes. In simple folding both sets of such joints would be parallel with the strike of the beds, one dipping with, and one against them.

The Adirondack Precambric rocks are much jointed. It is however a difficult region in which to obtain accurate measurements of the hade of the joints, though observations on the strike are easily obtained.[1] Moreover, in much of the district the rocks are igneous and poorly foliated, baffling any efforts to determine the structural significance of the joints. The writer's observations have been mainly made in such districts and are not yet sufficiently extended and worked out. Certain things are however clear.

The Precambric rocks are much more conspicuously jointed than are the overlying paleozoics, implying a time of joint formation prior to the deposition of the latter.

Joints are not equally conspicuous in all of the Precambric rocks, being least prominent in the limestones, and most so in the great igneous masses, implying some joint formation while the rocks were at sufficient depth to render the weak limestones somewhat plastic, though the igneous rocks were thoroughly rigid.

Four sets of joints are usually to be made out in the Precambric rocks, though all four are seldom present in any given exposure. Though varying considerably in direction from place to place, they can be apparently referred to two main sets, the one consisting of a pair of north-south and east-west joints and the other of a pair of northeast and northwest joints, both sets swerving in direction through 15° or 20°. In some exposures one set is the more prominent, in some the other set; in many at least three of the four show, and not infrequently all four. The north and east joints are usually vertical, or nearly so, while the others frequently show a greater hade. Not uncommonly, specially in the

[1]As in the case of a fault, the hade is the angle of inclination from the vertical.

great igneous masses, a nearly horizontal set also appears, but this is more intermittent and less regular than the others.

Since the usual foliation strikes of the region are either to the northeast or to the northwest, it is likely that the inclined joints in those directions represent compression joints in the shearing planes, these being more or less controlled by the foliation. An instance of the sort is illustrated in plate 15. The cliff there shown is a joint cliff, with a n. 50° w. direction, an important joint direction in the vicinity. Two sets of inclined joints cut the face of the cliff, both of which have a strike of n. 30° e. The one has a fairly uniform hade of 35° to the northwest, while the other is much more irregular, often swerving into a horizontal position, but in general hading to the southeast. The rock is augite syenite, with a very rude and imperfect foliation, which strikes about n. 40° e., closely approximating the strike of the joints. At the right of the view another joint set appears with a n. 70° e. strike and a hade of 15° to the south, and there is yet another nearly vertical set, not appearing in the view, which has a n. 20° w. strike. It would seem very likely here that the n. 30° e. joints are compression joints, produced in the shearing planes.

Such instances as the above are rather exceptional, however, and the usual, nearly vertical joints which prevail throughout the region have not yet been successfully classified.[1] That at least an east-west system had been developed in Precambric times is indicated by the prevalence of that trend in the diabase dikes. They vary from it through 20° or 30° both to the north and south, but within those limits have it so uniformly as to indicate not only the presence of a fissure system with this trend, but also that this set constituted the line of least resistance to the upward movement of the molten rock. This might have been because this was the only, or the best developed set, but more likely the use of it to the exclusion of other sets was determined by the direction of the side pressure which prevailed at the time.

That minor faulting has often occurred along these joints has already been set forth. It has not yet been determined whether

[1] Such for example as the n. 50° w. series of plate 15, well shown also in plate 16, a nearly vertical set which is quite persistent over a very large area in the mid-Adirondack region.

Plate 15

Cliff at southwest end of Bluff island, Big Tupper lake, showing joints, the cliff face itself being along a n. 50° w. joint

this slip faulting is of the normal or reverse type, that is, whether it took place under conditions of tension or of compression. But the whole aspect of the exposures indicates the action of compressive forces. The best localities for observing the conditions are in the rock cuts along the New York Central and Hudson River Railroad west of Saranac Inn station. All of these show the anorthosite to have been much shattered and sheared, with alteration of the feldspar to saussurite where the action has been most violent. There are four main sets of joints shown in the exposures: a nearly vertical n. 50° w. set, the steadiest and most persistent of all; a nearly vertical n. 80° e. set; a somewhat erratic set, shifting from n. 45° e. to n. 15° e. and not vertical; and a n. 20° w. set, often with a hade as high as 40°. The two latter are the ones which show shearing and slickensiding, and more specially the last one. The shearing planes are closely spaced, dividing the rock into very small blocks, and the minerals are much broken and brecciated. Both these sets appear to be compression joints, representing likely two different periods of compression, and the effect of the shearing would be much more likely to produce compression faulting than tension faulting. The brecciated rock recalls other brecciated strips of the region, notably those described by Kemp from Hammondville, Essex co.[1] These breccias sometimes have a chloritic matrix, but more often one in which quartz and chalcedony predominate and form hard, resistant rocks, so different from the rather loose masses of fault rock which characterize the Paleozoic fault planes of the region that they would seem unquestionably to be much older. That they mark lines of faulting is certain, and the Precambric age of this faulting would seem beyond dispute.

The Paleozoic rocks are invariably jointed, but in general but two sets are to be made out, they being vertical and at right angles to each other. They show a somewhat varying direction, but usually the more prominent set has a north-south trend, with the minor one running east-west. They are most irregular and least clean cut in the massive Potsdam and Beekmantown beds. They have approximately the direction of two of the

[1] 13th An. Rep't State Geologist, 1893. p.456.

sets in the Precambric rocks, but, because they appear less well marked, some hesitancy is felt in ascribing both to a single time of joint formation, specially in view of the evidence for the prior existence of at least an east-west set in the Precambric rocks. It is inferred rather that the coincidence in direction is merely a coincidence.

In the shaly rocks of the Cumberland head series, in the vicinity of Lake Champlain, the stresses which accompanied the folding of the district to the eastward were sufficiently felt to produce cleavage in the weak shales, though the more massive limestones and sandstones beneath were not affected. These shales are found cut by closely parallel cracks with hades of from 30° to 60°. The beds lie nearly horizontally, and this cleavage angle indicates rather a formation of fissility along the shearing planes than a true vertical cleavage in the compression plane. Sharply cut, vertical joints are also present, often in three directions. While the writer has never observed a like structure in any of the Champlain Utica which he has seen, yet the Utica always shows more indications of compressive disturbance, so far as folding is concerned, than any of the remaining Paleozoic rocks of the region. The explanation is undoubtedly to be found in the weak nature of the rocks as compared with the massive, resistant limestones and sandstones beneath, so that folding and shearing were produced in them by forces insufficient to affect the others correspondingly.

TOPOGRAPHY

Introduction

The topography of any old land area is a resultant of the joint action of two great sets of processes. Arising from beneath sea level with the comparatively smooth surface which it possesses because of the rather uniform deposit of sediments on it, it becomes at once subject to the erosive processes which hold sway on all land surfaces, in which atmospheric and aqueous agencies act jointly, but in which running water plays the major role. From time to time it falls under the influence of forces such as that which originally brought it above the sea level, forces originating in the earth's interior in ways not well understood. These vary its altitude with respect to that

level. The forces of erosion work incessantly and according to stereotyped methods, but cease their activity at sea level, hence tend to wear down the lands to a gently sloping surface, rising inland with recession from the shore line. The longer these agents are permitted to work at this task, without interruption from the other set of forces, the larger the proportion of the whole task which will be accomplished. The streams will progressively cut their valleys down to this slope, or grade, after which the work consists mainly in valley widening, bringing a steadily greater amount of the region down to the new level, with a constantly diminishing portion remaining at the old. During the progress of the work a varied topography will be produced, depending on a host of minor factors, rock arrangement and rock resistance being the two most important. The weak rocks will yield most quickly, and many of the streams will adjust themselves to these weak rock belts. The more resistant rocks will persist longer at the old levels, hence tending to become stream divides. The weak belts may be owing to weak rocks or to structural lines of weakness. The rock dip is a most important matter in determining the character of the valleys and uplands. Where it is gentle, flat topped divides and a tendency to radial valleys result. Where it is steep, parallel valleys and sharp backed ridges are produced.

Given sufficient time, the resistant rocks slowly reach the lower level, and the surface becomes comparatively smooth, the interstream areas having low, gentle slopes, with perhaps here and there a low hill or ridge of extraresistant material. Beginning as a plain, the district reappears as a plain, though less smooth than before. Such an erosion surface is known as a peneplain.

If now this process of wear is interrupted at any stage by an oscillation which changes the relative level of land and sea, the grade of the streams is altered, and the whole erosion process must recommence its work with reference to this new grade. If the movement be an upward one, the streams at once commence the task of cutting down the region to this new level, leaving their old task in the condition in which the beginning upward movement found it. Such portion of the region as had been worn down to grade, will carry this evidence of graded

condition upward with it to the new level, where it will persist for a considerable time and furnish evidence of a former graded condition at the lower level, as well as that the level has since been uplifted; its altitude above the new grade which the streams reach will also give the vertical amount of the uplift for the locality.

Prepotsdam topography

During the long existence of the Adirondack region as a land area, it has twice remained at a given level for a sufficient length of time to permit the reduction of almost its entire surface to the graded condition. The first occasion was in Prepostdam times, and the comparatively smooth surface on which that and the succeeding deposits were laid down, as shown on all sides of the region wherever this surface can be seen passing beneath the Paleozoic rocks, is the result. At the beginning of Potsdam time the district seems to have presented the aspect of a low, irregular dome, whose slopes were the gentle ones of the stream grades, and whose longer axis, or main watershed, extended across the region in a southeasterly direction, along a line running from a little north of Watertown to a little south of Albany, and also extended northwesterly into Canada. The streams drained away from it in all directions, but principally to the northeast and southwest. This axis does not divide the present Adirondack region into halves, but lies well toward its southwestern border, so that, at the commencement of Potsdam time, the sea was close at hand on the northeast Adirondack margin, but was many miles distant from that on the southwest; consequently the depression carried the one area below sea level, while the other still continued as a land area. This effect was accentuated by the more rapid subsidence on the northeast. Thus the sands, carried down by the streams and washed about by the waves, are now found only on one side of the district; on the other they did not reach the region, and now lie miles away from its margin, buried deep under newer deposits.

The surface covered by the Potsdam deposits on the north and east sides of the district, is found to be much rougher than that on the southwest, which remained unsubmerged during this time and was not reached by the sea till the following Beekmantown, or Trenton; and it is thought reasonable to suppose that this

greater smoothness is owing principally to this added length of time during which it was undergoing wear. Its irregularities are comparatively few and small; it seems a quite typical peneplain. On the north the irregularities are many and often considerable; are the rule rather than the exception. The surface is quite hummocky and hilly, and the contact line an irregular one. The supposed evidence is perhaps exaggerated in importance, owing to the possibility of undetected faults in certain localities, but is abundant even should all doubtful evidence be eliminated. It does however seem to be true that the irregularities are mostly of a minor order of magnitude, so that, when the tremendous thickness of rock material which was removed in this Precambric interval is taken into account, with the several uplifts, and the quite respectable altitude at times which are thus indicated, the surprise is not that the surface is so rough, but that it is not vastly rougher. Maximum differences of level of but a few hundred feet are all that are involved, and these comparatively seldom. Whether the surface were not sufficiently smooth to be worthy of the name peneplain, is merely a matter of the personal conception of such a surface which different individuals may hold.

The writer has shown that, in the Little Falls region, the present inclination of this old surface is about 100 feet per mile toward the south. The Beekmantown and Trenton rocks which rest on it have a present dip in the same direction of about 70 feet to the mile; whence, if we assume that they were deposited in a horizontal attitude, we obtain a slope of 30 feet to the mile as that which the old surface possessed at the time when the Paleozoic rocks were deposited on it. While this is a gentle slope, it is too steep for one graded by stream action and suggests that the movement of depression itself resulted in some further tilting of the surface. Little or no direct evidence has been obtained in other districts as to its amount of slope.

Paleozoic topography

If the Utica sea overswept the entire region, and all the available evidence seems to indicate that it did, then the region arose from beneath sea level with a smooth, constructive surface whose slopes depended mainly on the character of the uplift. But of this we

are in almost entire ignorance. Nor is there any evidence as to the altitude above sea level given to the region. Subsequent depression and deposit on the southern flanks of the region indicate that much of it had slopes to the south and southwest. How much effect the Taconic uplift may have had on the eastern border is a question, but the possibility of a sagging along the line of the Champlain valley, implying an easterly slope to the eastern part of the region, must be kept in mind. It seems therefore likely that the original character of the region, that is a low, domelike elevation, which slowly sank beneath the encroaching waters of the various early Paleozoic marine invasions, till it was finally overtopped, was renewed by this Postutica uplift, and that the elevation was of the low dome type. Its apex, however, was likely shifted from its former position in the southwest and moved northeastward. The effect of such an uplift would be to increase somewhat the slight initial dip of the sediments outward from the dome in all directions. An alternative view is that the region was merely an extension of the land areas which certainly existed to the north, and to the east during this time, and that it thus sloped, as a whole, to the southwest. In either case drainage would set up on the new surface, and would consist at first principally of streams which flowed down the sloping surfaces, or across the strike of the underlying rock beds. As they cut valleys, tributaries would commence to form, and these would adjust themselves to the rock beds, developing mainly on the weakest and flowing along their strike. With further uplifts, if such occurred, these would tend to extend themselves at the expense of the smaller original streams and lead them off as tributaries to the larger ones.

The Paleozoic cover on the old Precambric floor could not have been thick over the central portion of the region, and would likely have been first cut through there, reaching the resistant Precambric beneath. The area thus exposed would slowly increase in size, faced constantly on all sides by the retreating margins of the overlying rocks. These not only were of unequal resistance, but progressively increase in resistance downwards. Thus the Utica is weaker than the Trenton, that than the Beekmantown, while the Potsdam is most resistant of all to wear.

Consequently each would tend to be stripped away somewhat more rapidly than what lay beneath; thus a terrace would be produced on the bared surface of each more resistant layer as the weaker material above was removed [fig. 6]. This is the general character of topography which is everywhere produced in districts where the rocks lie nearly flat, are of unequal hardness and are undergoing wear. How much progress was made in its production, and how great an area was stripped of its Paleozoic cover during this special interval, it is impossible to say. With the passage of time, and with the increased possibility of wear brought about by later uplifting, the fronts, or infaces, of these

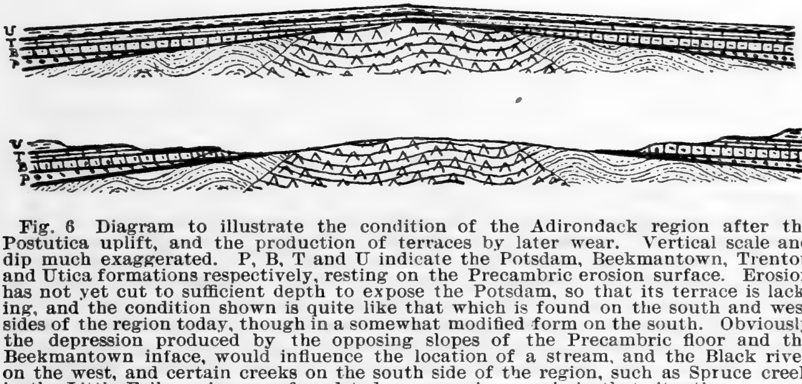


Fig. 6 Diagram to illustrate the condition of the Adirondack region after the Postutica uplift, and the production of terraces by later wear. Vertical scale and dip much exaggerated. P, B, T and U indicate the Potsdam, Beekmantown, Trenton and Utica formations respectively, resting on the Precambric erosion surface. Erosion has not yet cut to sufficient depth to expose the Potsdam, so that its terrace is lacking, and the condition shown is quite like that which is found on the south and west sides of the region today, though in a somewhat modified form on the south. Obviously the depression produced by the opposing slopes of the Precambric floor and the Beekmantown inface, would influence the location of a stream, and the Black river on the west, and certain creeks on the south side of the region, such as Spruce creek in the Little Falls region, are found today occupying precisely that situation.

terraces would steadily retreat away from the center of the region, without however changing their general character. They are today prominent on the south and west sides of the district, where they are accompanied and influenced by the infaces and terraces of the later Paleozoic rocks which there overlie them. On the east and north they are not conspicuous, owing to a variety of causes.

Appalachian uplift

The long period of Paleozoic erosion was terminated by uplift of the region, the movement being merely the local manifestation of the widespread movement of uplift and of dislocation which terminated the Paleozoic era in eastern North America. The forces which folded the region to the eastward, affected the Adirondack district but slightly, and the rocks are not folded.

But in the reaction of the region from compression, tension faulting took place on a large scale, and its eastern portion was sliced by the series of meridional faults which cross it. Since these uniformly downthrow to the east, they produced a step-like topography of eastward facing fault scarps, with intervening terrace platforms. In the Champlain region the faults were numerous, and often of large throw, their combined effect being to cause a rapid drop in altitude eastward, and to produce a depression along the Champlain meridian. But at the same time the region still further east was uplifted, mainly by folding and thrust faulting, thus outlining the Champlain valley as a great structural depression, or trough, closely coinciding in position

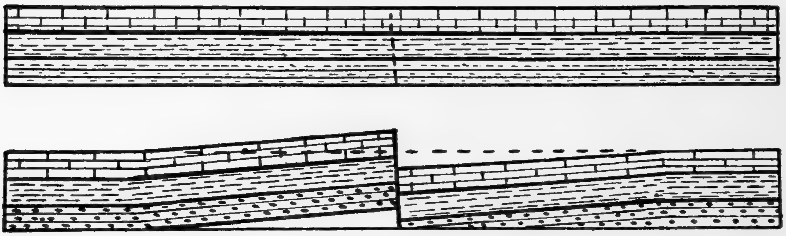


Fig. 7 Diagram of a single normal fault to illustrate the local character of the surface derangement. The rock layers on the upthrow side are given a dip away from, and those on the downthrow side a dip toward the fault plane, but at the ends of the figure the rocks remain as before the faulting.

with the previous depression of the Chazy basin. The region directly to the west of this depressed strip was given considerable altitude by the general elevation, and it seems likely that it formed then, as now, the most elevated portion, with a rapid step-like drop to the east, and a gentle and more even slope toward the west. Passing westward, the faults become much fewer in number, and, while they interrupted the prevailing westerly slope with their scarps, the interruption was but local [fig. 7]. This is well illustrated by the Mohawk valley faults, in whose vicinity a strong increase in the westerly component of the dip is always observable, which flattens back to the normal amount with increasing distance from the fault.

In some few cases trough faulting was brought about by a pair of faults throwing in opposite directions, and depressing the block between. Between the Little Falls and Dolgeville

faults in the Mohawk valley was a block of this sort. Apparently the Paleozoic inlier at Wells, Hamilton co., is preserved in a similar trough. In the Precambric areas to the north, specially in the high Adirondacks, the topography often suggests faulting of this sort. And, as has been shown, cases of this kind are not infrequent between the minor cross faults in the Champlain region.

In addition to the modification in the topography produced by the erection of the fault scarps, the faulting must obviously have affected the drainage. Stream courses would be obstructed by the scarps and the streams turned into parallelism with them, tending to flow along at their bases; and the crushing of the rocks along the fault plane would produce a line of weakness there, which, even after the disappearance of the scarp through wear, would tend to hold the streams there.

Mesozoic base-leveling

This uplift, which terminated the Paleozoic history of the region, obviously renewed the activity of the erosive processes, and the task of cutting down the region toward the new base level thus given it was begun. Though the evidence is not as clear as could be wished, it points to the region having remained at this newly given level for a long time, long enough to permit the wearing down of the major portion to a comparatively even surface at this new stream grade. In other words, it was worn down to a peneplain, above whose general level certain hills of various altitudes arose, none of which exceeded 1000 feet in elevation, which had resisted somewhat the general wearing tendency, mainly because of advantageous situation. The infacing escarpments of the Paleozoic rocks retreated well away toward the margins of the region, till the weak belts reached grade, after which the escarpments would disappear as the stronger rocks slowly came down to the same level; the fault scarps also disappeared, both sides coming down to the general level; the streams which were flowing parallel to the sides of the region, adjusted to the weak rock belts, would accompany these belts in their movement away from the heart of the region; they would also increase in size by the capture of many of the

outflowing streams, leaving only the largest and most advantageously situated of these in their old courses.

It has been shown that the later Mesozoic was a time of widespread base-leveling over much of the eastern United States, notably in the Appalachian region and in southern New England. While subsequent wear has removed much of that old surface, the many fragments that yet remain indicate, by their concordant summit levels and by their level ridge crests, that they are remnants of a former plain; and that it was an erosion plain is shown by the fact that its surface is notably discordant with, or bevels, the rock beds. An extensive erosion plain of the sort can only be produced, on a land surface, at stream grade, and during a protracted period of comparative stability of level.

It has been further shown that this plain has been tipped by subsequent movements, the evidence for which is the present diminution of altitude in certain directions. Thus the uplift of the Cretaceous peneplain of the Appalachians was greatest along a n.n.e.-s.s.w. axis, from which the old surface drops both to the east and to the west. The uplift was also unequal along the axis, being greatest in Virginia and descending both to the north and the south. The peneplain of southern New England, which is supposedly of the same age, is strongly tipped toward the south.

This uplift was followed by another period of comparative stability, during which large progress was made in reducing the surface of these districts to the new base level. This interval was not, however, so protracted as the previous, so that the region was only partially base-leveled. Broad valleys were opened on the weak rock belts, while but little progress was made in the reduction of the resistant rocks, which remain substantially at their previous level, and form today the remnants of the Cretaceous peneplain.[1] The widely opened valley bottoms on the weaker rock belts, with their concordant altitudes when compared with one another, furnish the main evidence for a long stability of the region at this grade.

[1]Campbell has recently urged the presence of a base level intermediate to these two, from evidence obtained in northern Pennsylvania and southern New York. Geol. Soc. Am. Bul. 14:277–96.

This is no longer the grade of the region, a comparatively recent movement having elevated it, and the streams are now busily engaged in the task of getting their beds down to the new grade and of widening their valleys. They are yet far from being thoroughly adjusted to the new conditions.

Peneplains

It would seem inherently probable that the Adirondack region participated in the actions outlined, but several causes conspire to make the evidence less clear than in the other districts mentioned. In the southern and western portions of the region, however, the hilltops do, in general, rise to quite concordant levels, which are wholly independent of the rock attitude and structure, and the inference is irresistible that they rise to the level of an old and comparatively even erosion surface, quite

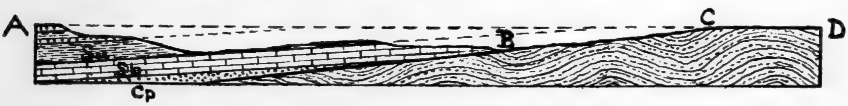


Fig. 8 Somewhat ideal section from north to south across the Mohawk lowland. The Cretaceous peneplain surface extended across the region from A to D. Following the uplift, the intervening region has been worn down, owing to the weak character of the limestones, Sb, and the shales, Su. The harder rocks at A, and from C to D, have resisted wear and remains at the old level. Erosion has not yet reached the horizon of the Potsdam sandstone, Cp. The wearing away of the limestones has bared the underlying Precambric rocks from B to C, exposing the old, Precambric erosion surface, which meets the Cretaceous peneplain at a small angle, which the large vertical exaggeration of the diagram makes altogether too prominent.

Fig. 9 shows the angle drawn to true scale, the upper line representing the CD, and the lower the BC slope.

likely a product of the same great erosion period which elsewhere developed the Cretaceous peneplain. The probability is hightened when it is seen that the prolongation of this surface southward, above the Mohawk lowland, to the plateau of southern New York, finds it in close correspondence with the upland levels there, as if the two were developments of the same great surface [fig.8]. In both districts, too, this surface is now tipped to the west.

This old peneplain is best preserved in Hamilton county, though well marked also in Herkimer and St. Lawrence. On the west and south margins of the region it is replaced by another

erosion surface of different slope and origin. This has its rise in the very resistant character of the Precambric rocks when compared with the overlying paleozoics, specially in districts where the Potsdam sandstone is thin or is absent, as it is on the west and south. During a cycle of wear, these weaker rocks are stripped away from the underlying Precambric, whose old erosion surface thus reappears, and tends to maintain itself for a time, owing to its extraresistant character [fig. 8]. Thus is produced a considerable strip of Precambric rocks on these two sides of the region, with an even hilltop line, which comes to this level, rather than to that of the Cretaceous peneplain. It, however, slowly rises to meet, and insensibly merges into that.

Quite a number of monadnocks, as residual hills which are not worn down to the general peneplain surface are called, exist in the region, their summits reaching a few hundred feet above the general hilltop level. They are not sufficient in number to obscure the general level, though they do somewhat disguise it.

In the same districts the later base level is also indicated by the rather broad valleys and their comparatively uniform levels. It is also observable that, in passing toward the heart of the region, the valleys are deeper cut, in other words, that the vertical interval between the two plains increases, indicating that the Cretaceous peneplain was tipped when elevated, and that the uplift was greatest on the northeast, so that it is now canted considerably to the west and slightly toward the south.

In the eastern Adirondacks the above features can not be satisfactorily made out [pl. 16]. There is little concordance in the summit elevations, so that either the district was not reduced to a Cretaceous peneplain, or else that surface has been dislocated, and given varying altitude, by subsequent movements. Possibly both may be true, and there is some evidence which points to the dislocation having actually taken place.

Recent uplift has affected the entire Adirondack region, in common with a much larger area, and this uplift has been greatest on the northeast. It has amounted to at least 400 feet at the south end of Lake Champlain, and at least 550 feet at the north end, and to 250 feet or more at the east end of Lake Ontario. And these are minimum figures, which must likely be much increased when the entire movement is taken into consideration.

Plate 16

View of the Seward range from the Hiawatha House, on Stony Creek pond. The summit is 8½ miles distant

It is not certain whether it has ceased or is yet in progress, though the latter is very probable. The streams are working their way down toward the new grade, but have made comparatively slight progress in the task.

Main axis of elevation

The highest elevations in northern New York occur along a line which, commencing at the national boundary on the north, runs south along the line between Clinton and Franklin counties, till it reaches the district of the high peaks in northwest Essex. Here it offsets sharply to the west, into southern Franklin and northern Hamilton counties, then turns again toward the south and runs down through Hamilton, in this part of its course trending about s. 20° w. instead of nearly due south, as at first.[1] In this change of trend a rude parallelism with the folded rocks to the eastward is to be noted, these also swerving toward the west in passing into New York from the Vermont side. This probably implies an interrelationship between the two, at least in so far as the original location of this main axis is concerned.

Along the Hamilton county portion of this main axis are found the greater number of, and the larger of, the monadnocks which protrude above the Cretaceous base level south of the mid-region. They are so numerous that, were this area alone concerned, the Cretaceous base level would be difficult of recognition. Parallel with the eastern edge of this uplift is a rather deep and wide valley, eastward from which the region is much more dissected, and with considerably lower hill altitudes. The features strongly suggest that the eastern face here is along a line of fault.

The abundance of monadnocks in this district would indicate that, during the period of Cretaceous base leveling, the main divide of the southern district must have been hereabout, just as it is now, since the rocks are not more resistant here than elsewhere. They must therefore owe their preservation to favorable position.

Among the high Adirondacks in Essex and Franklin counties the country is still more rugged and uneven than in Hamilton, so

[1]On a small scale these features are well shown on the "Map of New York showing the Surface Configuration and Watersheds," recently published by the State Museum.

much so that no sign of concordance of level is to be noted among the hill summits.

This main axis of elevation is everywhere so pronounced that it would seem that it could hardly be a feature which had outlasted the long period of Cretaceous base leveling, but that its present prominence must be owing to unequal uplifting at the close of this erosion cycle. The considerable deepening of the valleys in passing toward the heart of the region (the broad valleys cut in the succeeding erosion cycle are the ones here concerned) points clearly to greater uplifting along this line. It also seems likely that, in a region of abundant faults such as this is, such an uplift could not fail to cause additional adjustment along the fault planes. Such movements would give varying altitudes to such portion of the area as had been graded during the long erosion period. That many of the tops of the high Adirondacks are true monadnocks, is highly probable. But that the area is entirely composed of monadnocks, and never had any recognizable development of the Cretaceous peneplain on it, is thought to be exceedingly improbable, much more so than the alternative view here presented. And this is emphasized when the rapid drop in altitude to the Champlain valley is taken into account, both its rapidity and its character suggesting rather recent faulting.

On the prolongation northward of this main axis, the same features are illustrated in the Paleozoic rocks, these being found at the highest altitudes along that line, dropping rapidly eastward down the faults and less rapidly, and more regularly westward. This represents the total amount of tipping which they have received in all the movements of the region, but the present prominence of the axis as a topographic feature seems too great to be accounted for otherwise than by a not too remote date for the last differential movement along it. In addition, certain prominent eastward facing cliffs which appear to be fault scarps, are found in the Potsdam country, just as they are in the Precambrian areas, fault scarps which seem to require actual faulting of comparative recency to account for their presence. The evidence, then, seems to point to actual warping of considerable

amount along this axis during the uplift which terminated the Cretaceous erosion cycle, with accompanying downfaulting on the east, giving the fragments of the Cretaceous peneplain varying altitudes and increasing the prominence of the Champlain depression.

Lake belt

In southern Franklin county, nestling in the angle produced by the offset of the main axis of elevation to the west is an area of broad valleys and low ridges in which lakes are more thickly clustered than in any other part of the region, and for which therefore the name " Lake belt " has been suggested, for the lack of a better term. The valley bottoms have the same levels that they have in adjacent districts, but the ridges are low, commonly only 200 feet or 300 feet high, not by any means attaining the levels that they do in the country east, and considerably lower than the summits in the other direction, though the discrepancy is not so pronounced. The relief is in general insignificant. All the ridge summits are well beneath the horizon of the Cretaceous peneplain level.

No cause for this discrepancy is to be found in the character of the underlying rocks. These are anorthosite and syenite for the most part, the most resistant of all the Adirondack rocks. The rocks of the Lake belt are in no sense weaker than in the areas of higher altitude and greater relief adjoining, are in fact stronger than those to the west.

The belt has many features which indicate that the main preglacial drainage systems passed through it; and this would necessarily tend to lower its general level more rapidly than would be the case at a greater distance from the main drainage lines. But the fact that it is sharply separated from the adjacent districts instead of fading into them, with no change in the rock character, and the abundant rock ridges, all of small altitude and none reaching at all nearly the Cretaceous base level, seem to require a structural cause for their explanation; and it is regarded as a probable dropped fault block, the district to the east having been

greatly uplifted as compared with it, that to the west considerably less so. Its own hilltops reach concordant levels, and probably represent the Cretaceous base level, but dropped below its normal altitude.

Faults as topographic features

As has been stated, it is probable that all fault scarps in the region disappeared by being worn down during the Cretaceous base-leveling period. Such wearing down customarily brings different rock masses into juxtaposition on opposite sides of a fault. Any renewed uplifting of the district then tends to cause a reappearance of a scarp along the fault line, owing to the more rapid wearing away of the weaker of the two rocks. The hight that this scarp may attain will have the difference between the old and the new base levels for its maximum value, and the proportion of this actually attained will, other things being equal, depend on the comparative resistances of the two rocks. If one is very strong and the other very weak, relative prominence may be gained, specially in the near vicinity of drainage lines. The weaker rock may be on either the downthrow or the upthrow side, and, according as the first or the second is the case, the scarp will face in its original, or in the opposite direction, in the latter case giving rise to the anomaly of the downthrow side standing at a higher level than the upthrow. In the cases where there is little or no difference in resistance between the rocks on the two sides, there will be no tendency to cause reappearance of a scarp along the fault line.

Furthermore, except in the case of faults which exactly parallel the strike, the surface rock will vary from time to time on the same side of the fault, and with these changes, now on one side and now on the other, the scarp becomes either less or more pronounced than it was before, as the variation diminishes or increases the difference in resistance of the rocks. In the case of dip faults an irregular topography is sure to be produced along the fault, owing to the more frequent passage from one sort of rock to another.

In general, the faults of northern New York show a weaker rock on the downthrow side and hence tend, on uplift, to reproduce a scarp facing in the direction of the original one.

There are however numerous cases where the resistance is practically uniform on both sides.

In the Mohawk valley region there is no evidence of any recent faulting. The faults are quite typical dip faults, in a district of low dip. Since the Paleozoic rocks there, from the Beekmantown to the Utica, are progressively weaker upward and are all weaker than the underlying Precambric, it necessarily follows that the faults everywhere show weaker rock on the downthrow side, except where the same formation occurs on both. Owing to the recent uplift of the region, the scarps are coming into prominence, specially where they are crossed by streams. In fact, the utter independence of the faults shown by the streams here, is one of the strong arguments against any recent movement along the fault planes, and for such present day prominence as they have being wholly due to the recent uplift of the region.

Along the Mohawk the faults show great cliffs facing eastward, the valley widely opened in the weak shales on the downthrow side, while constricted and gorgelike in the resistant Beekmantown or Precambric rocks on the other. Receding from the river, their prominence is at once lost, and the scarp is either not manifest or but feebly marked. Thus the Little Falls fault, a very noted topographic feature at the river crossing, loses this character entirely a short distance south of it and has no great prominence on the north, when the great difference in resistance of the rocks is taken into consideration. Eventually it passes wholly into Precambric territory and can be no longer traced. While this may be because of the dying out of the fault, there is no evidence that this is the case. If, on the south side, the fault could be followed through the Utica shale belt to where the more resistant overlying rocks appear, these would come in first on the downthrow side, with production of a scarp facing west.

In the Paleozoic limestones along Lake Champlain, which have great thickness, but no marked difference in strength, the fault scarps are in no way conspicuous at the present day; in fact, at low altitudes there are none at all. At higher levels, however, they appear. Thus the Tracy brook fault shows no scarp in that part of its course shown on the map [pl. 12], notwithstanding it

has resistant Potsdam on one side as against weak limestones on the other. Farther southwest, however, where it passes into higher ground, the prominent east face of Rand hill is its scarp. So far as these low altitude faults are concerned, they give no evidence of recent faulting.

Some slight relief has been produced along some of the small cross faults, in cases where the dip is fairly high, 10° or more. These are dip faults; and, since the limestones which they cross have slightly variant resisting power, the more massive beds stand slightly above the surface as ridges, and their lateral shifting by the fault is clearly brought out in the topography. The Black river limestone, and some of the beds of the Crown Point division of the Chazy, are the more prominent ridge makers of this type. This topography is very characteristic of the cross-faulted strip shown in plate 12.

The drainage is not so independent of the faults in this district as it is along the Mohawk. Many of the streams follow the fault lines for considerable distances, Tracy brook and the Little Chazy river, as shown in plate 12, for example.

It is however in this eastern district that the evidence of recent faulting is forthcoming. In the rapid rise in altitude from the Champlain level to the main axis of elevation, which is from 25 miles to 30 miles west from the lake only, are many eastward facing cliffs which resemble fault scarps. The larger number of these show equiresistant rock on both sides. Thus there are apparent faults which are wholly in the Potsdam, having that rock on both sides and with no detectable difference in the resistance, which, notwithstanding, present a prominent easterly cliff. Wear, because of renewed uplift, could by no possibility have brought out this topographic relief; and, in the total absence of evidence of any other mode of origin, a belief that they are fault scarps is compelled, necessitating the further belief that they can be no older than the date of uplift of the Cretaceous base level, and may perhaps be younger.

The majority of the supposed faults are in Precambric rocks. In many cases there seems little difference in resisting capacity of the rocks on the two sides, and in certain cases the rock is

identical. There are several cases in which the presence of the scarp can not possibly be owing to differing rock resistance, so that the only element of doubt in the matter concerns the actual existence of the faults. They are very difficult to prove under such circumstances, yet it seems practically certain that they must be there.

North plain

On the north side of the Adirondacks a gently sloping plain extends from the Precambric boundary down toward the St Lawrence. It is warped upward along the north extension of the main axis of elevation, hence has a northerly pitching axis along this line, with northeast and northwest surface slopes away from it. These are but gentle, some 20 feet to 30 feet to the mile. The underlying rocks are the Potsdam and Beekmantown formations, which have a low, northerly dip. This is however considerably greater than the surface slope, amounting to from 100 feet to 200 feet to the mile, so that the rock layers are beveled by the plain surface, progressively higher beds being exposed going north.

The general surface has received a comparatively smooth veneer of glacial deposits, supplemented by the deposits of running and static waters during and after the ice retreat. Low moraines constitute the principal present irregularities. There is no Beekmantown inface, for example, though this may be lacking because of being planed down by the ice sheet. Rock outcrops are so scarce in the region, however, that there is no opportunity to determine whether this is the case, or whether the inface has been buried beneath the drift. The old stream valleys have been filled up, and the streams have since somewhat reexcavated them though, since they have not accurately followed the old channels, they have met rock at small depth in spots where they have missed the track, and this has greatly retarded the reexcavating process. The plain retains approximately its preglacial slope, but its irregularities have disappeared through

blanketing. It lies below the Cretaceous peneplain level, having been worn down below that in the Postcretaceous erosion cycle.

The Precambric boundary presents quite different characters on the north from those seen at the south. It is much more sinuous and much more abrupt. There is no Potsdam inface, and the Precambric rocks are apt to tower somewhat abruptly from 25 feet to 100 feet or more above the Potsdam level. Between these outlying ridges embayments run, carrying the slope of the plain in between the ridges, and in many of these embayments the Potsdam is found, lying between the gneisses of the adjoining ridges. Faulting has undoubtedly played some part, perhaps a major part, in the production of these features, but it does seem quite clear, nevertheless, that the shore had a steeper slope than on the south, and that the surface was much less even.

Northern hills and valleys

The ridges and valleys of a large part of the Adirondack region show a general north-south to northeast-southwest trend, this being more prominently the case in the eastern half of the region. The precise cause for this general trend is not clear. The larger faults have this direction and are undoubtedly influential factors in the topographic control; the strike, both of the foliation and of the Grenville bedding, has often the same direction, and has no doubt its share in determining the topographic alinement; one main joint set has the same trend and may also be a factor; finally, the ice sheet moved over the district with a south to southwest direction; and, though the direction of the basal currents was mainly controlled by the existing topography rather than the topographic trend a result of the ice direction, yet some share in the general shaping of the region must be allotted to it. It seems likely that all these factors have combined in the production of the present trend; but it is as yet wellnigh impossible to determine definitely their relative importance. The frequent independence of this trend shown by the strike naturally suggests that it is of less importance than the others. The prominence of other joint sets, in addition to

those trending with the ridges, indicates that they were not the controlling factor, but that the direction was determined by something else, and, once determined, this joint set becomes of greater importance than the others. By a process of elimination, the faults seem to remain the most probable controlling factors in the original determination of the trend.

The present valleys were excavated below the Cretaceous base level in the Postcretaceous erosion cycle. The comparative weakness of the Grenville rocks determined valley location where they were present in any force, and a respectable number of the valleys of the region are of this origin. They are most numerous in western Essex and St Lawrence counties, being comparatively infrequent elsewhere. There are also many valleys in which one or more small patches of Grenville rocks may be found, surrounded by others of a different nature; and in these it is quite possible that the Grenville patches are merely the final remnants of much larger Grenville masses, which determined the location of the valley and have disappeared in its formation. But even where a very large allowance is made for possible instances of this sort, it yet remains true that Grenville rocks make small show in most of the region, and that the larger number of the valleys can not have been located on Grenville belts; are developed in fact in rocks identical in kind with those which make up the neighboring ridges. To account for these, it seems necessary to invoke some structural cause, and such may be found in belts of rubble rock along the faults, in belts of excessive jointing and slip faulting, and in the location of streams by the original fault scarps; also in the production of actual fault valleys (*Graben*). These are truer in direction than the Grenville belts and best explain the prevalent trend.

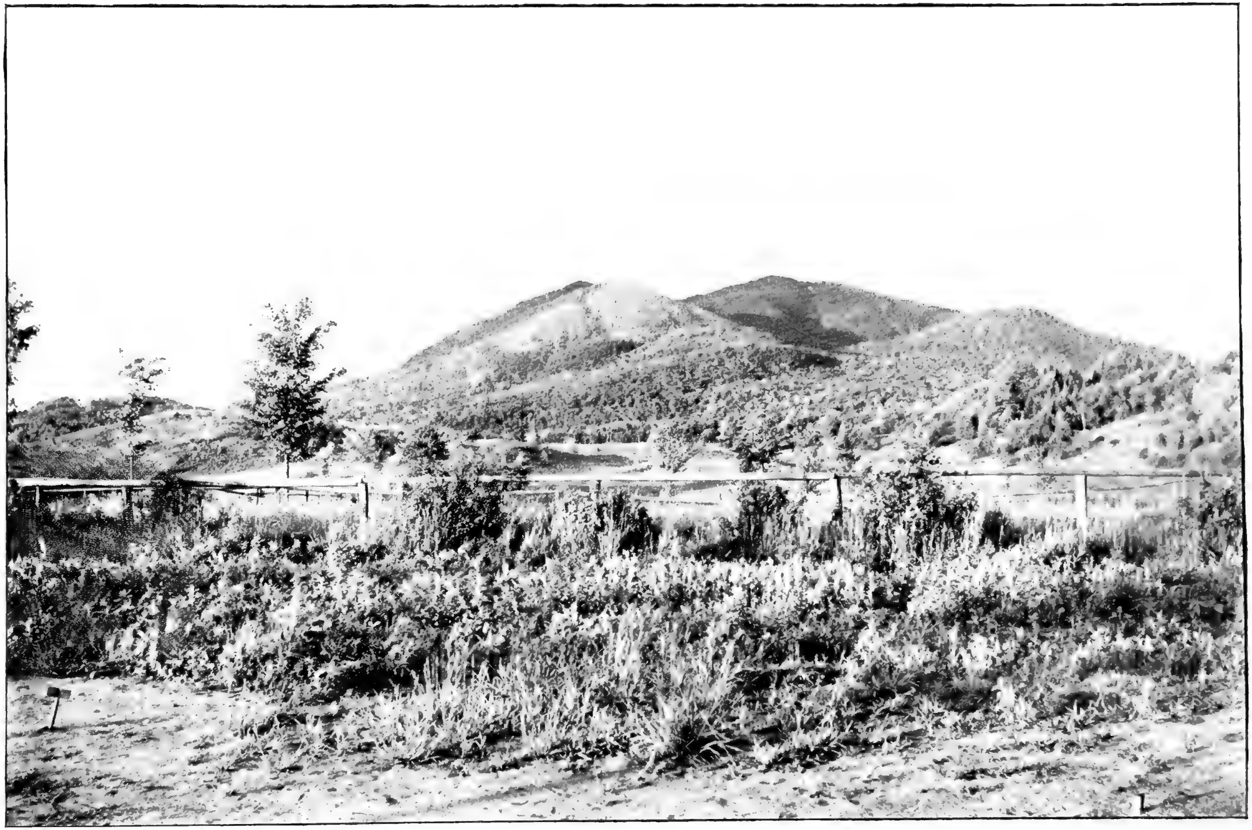
The larger number of the ridges of the northern Adirondacks show a certain type of configuration which calls for explanation. They have a long, gentle, even incline to the northeast, a summit well toward the south end, and a steep back slope, often in part a perpendicular cliff and in general steepest at the top. These features are seen most typically on the smaller ridges, but the larger ridge masses show a tendency to the same type. At the backs of these an amphitheater is apt to be developed, sometimes

of the typical cirque shape, and always strongly suggestive of glacial action [pl. 17]. Precipitous rock cliffs are always a feature on this side, while wholly absent on the gentle north slopes, on which rock outcrops of any sort are infrequent. The writer has often searched the north slope of such a ridge without finding a single satisfactory outcrop, while they are certain to be abundantly found when the summit and back slope are reached.

In the high Adirondacks, in the anorthosite region, these features are not found, the cirques excepted, and these are found along the flanks of the ridges as well as at the back. Stony Creek mountain [pl. 17] is an anorthosite mountain and on the edge of the high peak district, but it exhibits the general features just noted very imperfectly. They are better shown in many of the syenite peaks and in the main seem confined to the ridges of foliated rocks. The syenites always show more foliation than the anorthosites. Yet the writer has been unable to discover any connection between the strike and pitch of the foliation and the trend and pitch of the ridges; and, if any such does exist, it is obscure, though the facts noted above suggest some relationship.

That much of the shaping of the ridges has been done by glacial action seems clear. The northern hills are the ones mainly concerned, those so situated that they would feel the full force of the onset of the southwestwardly moving ice, after its advance, unimpeded by any obstacles, over the plain to the north. It must have impinged heavily on the north slopes of the hills, and the basal currents moving up the intervening valleys must have closely hugged the ridge sides. There would be at first a tendency to wear down all projections, and later to fill up depressions and blanket the slopes with till and moraine stuff. The lee side of the ridge, however, would not be closely enfolded by the ice, so that little smoothing would be done there. In the waning stages of the ice sheet a *bergschrund,* or *crevasse* between the ice and the back slope of the mountain, would be formed, in which a daily variation of the temperature from thawing to freezing would take place during a large part of the year, which would cause a rapid scaling off of the rock along the joints, producing rough, steep cliffs. During the wan-

Plate 17



Stony Creek mountain from Axton, looking east northeast. Distance to the summit 3¼ miles. The mountain is not of the typical ridge type though it approximates it. It broadens out on the southwest and sends out two spurs with a deep amphitheater between

ing of the ice sheet or at a somewhat later period, small local glaciers appeared high up on the mountain sides which, grinding away at their beds, with this *bergschrund* action at work on their sides, excavated the amphitheaters. But, while the ridges have thus been ice-sculptured, it is wholly unlikely that they were produced by glacial action. The ice found the ridges and valleys when it entered the region and merely left them somewhat modified. Some of the back slope cliffs strongly suggest fault scarps. One for example, suggests a fault across the ridge crest which has dropped its southern portion and produce the cliff and terrace outline. There is but a single sort of rock in that ridge, a resistant quartz syenite gneiss, so that the topography can not be accounted for by varying rock resistance. The sudden manner in which many of the ridges are chopped off at the south is very indicative of faulting. If faults are present, they are cross faults, since the main ones parallel the ridges. It is an exceedingly difficult matter to determine just how large a share the faults have had in determining the present situation and character of the ridges.

Streams

The working out of the varied history of the Adirondack streams is a matter of the future. No one has yet had opportunity to give the problem the thorough and exhaustive study that it requires. Furthermore, it is a difficult problem, owing to the great age of the land area, the several oscillations of level which it has experienced, the difficulty of determining the controlling factors in the Precambric district, and the many changes produced in the drainage by the action of the ice sheet.[1]

The general drainage of the present day runs radially outward from the main axis of elevation, and in part these streams seem the lineal descendants of the original consequent streams. Since

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[1]No attempt will be made in this paper to discuss the Pleistocene history of the region, since little connected work has hitherto been done on it. and because Professor Woodworth is now at work on the problem. Much information may be gained from papers by Brigham and Ogilvie. Geol Soc. Am. Bul. 9:183–210; Jour. Geol. 10:397–412.

a blanket of Paleozoic sediments probably covered the entire region, these original streams soon became superimposed streams, and showed no adjustment to the Precambric rocks which they uncovered in their beds during the stripping away of the Paleozoic cover. The present valleys are largely adjusted to these rocks, and this adjustment has been brought about by the successive uplifts of the region, each new cycle of wear tending to make it more perfect. The adjustment is in part on the weak rock belts and in larger part on the weak rock structures.

The Champlain valley has been shown to be a structural one, and as such to be the inevitable site of a drainage system. The subsequent origin of the Mohawk and Black rivers has also been indicated and had been previously emphasized by Brigham and others. The St Lawrence valley has also the character of a subsequent valley, as was first pointed out by Westgate; but, as it was the site of an old Paleozoic trough of depression and deposit, which seems to have been deepened by subsequent movements, this would appear to have had some share in determining its position. With successive uplifts of the region, the Mohawk and Black river valleys move laterally outward. This is not the case with the Champlain valley.

The outflowing Adirondack streams of the present are thus all tributary to streams which parallel the sides of the region. Those outflowing to the west and south are but the remnants of the consequent streams which continued on in those directions before the development of the Mohawk and Black river valleys, as Brigham pointed out. They rise near the main axis of elevation and flow in valleys cut in its gentle westerly slopes. Beginning at the southwest with West Canada creek, apparently only recently transferred to the Mohawk drainage from the Black, all the westerly streams, the Moose, Beaver, Oswegatchie, Grasse, Raquette, St Regis, Deer, Salmon and Chateaugay rivers, have this general character. All have been affected and modified by the ice sheet; but these modifications are local, and otherwise these streams rise near the main axis of the region and course down its westerly slopes, to the southwest, the west and the northwest. The abrupt

deflection of the Oswegatchie, Grasse, Raquette and St Regis from their normal northwest courses to a northeast direction, so that they flow parallel to the St Lawrence for many miles before emptying into it, is an interesting feature which has not yet been explained, though probably not difficult of explanation when the ground is thoroughly studied. The Oswegatchie emerges on the Precambric rocks of the Frontenac axis, and its behavior is obviously controlled by the topography, as it takes a subsequent course parallel to the ridges. But the other three streams make their bend on the northern Paleozoic plain, and the cause can hardly be a structural one. It must be sought in the Pleistocene features of the region, either this portion of the plain having a general slope to the northeast, owing to unevenness of glacial deposits, or else morainic or beach ridges being the deflecting cause.

The streams of the eastern Adirondacks mostly rise in the neighborhood of the high peaks. The Hudson and Ausable have their head waters in the high passes of that district. The Schroon and Sacandaga head in the ridges east of the main axis. The Saranac, on the north, heads in the Lake belt and is the only one of the principal streams to cross the main axis of elevation, both of its branches so doing. That portion of it which lies west of the axis is separated from the present Raquette and St Regis systems by the most trivial of glacial divides, and undoubtedly drained to the westward formerly. The date of capture by the Saranac is not known. The easterly flowing Adirondack streams have an advantage over those flowing west, owing to their steeper slope, and tend therefore to extend their head waters westward, causing the divide to migrate in that direction, away from the main axis. That the capture occurred in preglacial times seems very probable.

Farther south, in eastern Hamilton county, the main axis is crossed by two broad valleys, one running east from Long lake and the other from Raquette lake. These are however located on weak Grenville belts, on which it was easy for streams, flowing eastward from the main axis, to push their divides westward

across the axis. The modern divides in that region seem of glacial origin, and our present knowledge does not suffice to determine how much of the drainage west of the axis had been captured in preglacial times. That the drainage of the Long lake and Raquette lake valleys went out to the northwest in preglacial times is exceedingly improbable, and it may well have gone eastward to the Hudson.

The fact that the main axis of the region is to so large an extent the modern watershed, is the strongest of the arguments for its prominence having been given to it in comparatively recent times.

The northeastern streams, the Ausable, Saranac, Big Chazy and English rivers, flow in general northeast courses away from the main axis. Faults control them somewhat, and here the direction of the main faults is also that of the consequent stream flow. The upper Ausable and Saranac are, in part at least, controlled by faults. In their lower courses all cut across the strike of the Paleozoic rocks.

It is in the southeastern part of the region that the streams show the most marked adaptation to the structures, as was noted by Brigham on the publication of the first topographic sheets of the region.[1] The main streams here have n. to n.n.e. or s. to s.s.w. courses and receive their main tributaries from the west. Such Grenville belts as occur trend with the tributaries rather than with the main streams, and the determining cause of location is obviously a structural one. Ogilvie argues that the faulting was accompanied by block tilting toward the east, that the main drainage lines are located along the faults, and that the tributaries on opposite sides work against an abrupt fault cliff on the one hand or down a gently tilted slope on the other; that those down the slope have a conspicuous advantage and have extended their courses much farther back than those flowing in the opposite direction.[2] That the main streams follow the fault lines, the writer quite agrees. And, if the faults downthrow to the west, the rest necessarily follows. But, if they are normal

[1] Am. Geol. 1898. 21:219.

[2] Jour. Geol. 10:408.

faults downthrowing to the east, as most of the proved faults of northern New York are, it is more likely that the surface tilting would be to the west. It would also seem that the streams down the fault scarp would have an advantage over those down the back slope, because of their much steeper grades, and that originally the main tributaries would be westerly flowing streams down the back slopes, but that the streams down the scarp would lengthen at the expense of the others, pushing the divides westward. If now the main streams are at successively lower levels going eastward because of step faulting, these easterly tributaries would have that additional great advantage over those flowing west, and would not only tend to extend themselves at the expense of the westerly streams, but also to work back to, and to tap and lead off portions of the larger streams to the westward. Inspection of the maps shows many such apparent captures of the main streams by the easterly tributaries. If the writer be correct in his belief that these are the main structural features of the region, the assumption of the abnormal easterly tilting of the fault blocks seems unnecessary.

The great and abnormal bends to the northeast which are made by both the Hudson and the Sacandaga, some 15 miles to 25 miles north of the Mohawk line, would seem to be wholly modern and owing to glacial action. As a result of this swerve, no stream of respectable size enters the Mohawk eastward from East Canada creek, the drainage all turning east to the Hudson, while the divide between the streams flowing south to the Mohawk and those passing east into the Hudson, parallels the Mohawk and is distant from it only 15 to 18 miles. These features are excellently shown on the new, small scale topographic map of the State and strongly suggest a morainic divide, and that the Sacandaga formerly came down to the Mohawk in the Amsterdam region. The modern stream which flows northeastward from Gloversville and empties into the Sacandaga at the big bend, would seem to occupy this valley. Obviously a considerable shifting of divides must take place here in the near future, the present arrangement being highly unstable.

Chamberlin long since urged that the preglacial divide or col in the Mohawk lowland, between the drainage east to the Hudson

and that west to the Ontario valley, was at Little Falls, the location being determined by the Precambric rock mass there, brought up by the Little Falls fault.[1] Brigham has urged that West Canada creek was, at that time, tributary to the west flowing drainage, which he names the Rome river, coming into the valley at Oriskany by way of Holland Patent.[2] While the writer quite coincides with this view, he is also disposed to the belief that this route is comparatively modern, representing a capture of the upper part of the Black river drainage by a tributary of the Rome river. Black creek, the main tributary of West Canada creek, flows along the Precambric boundary in a northwesterly course, and seems unquestionably to represent the former upper portion of the Black river, as is shown in an excellent manner on the new topographic map. There is heavy drift filling between, but no sign of any rocky col, and the tributaries from the northeast show perfect parallelism with the Black river head waters coming down from the same direction.

Youthful character of the present drainage. During the withdrawal of the Laurentide glacier from the northern Adirondacks, the preglacial stream courses cut in the valley base level were completely filled with glacial deposits, while at the same time the irregular floor of the valley base itself was covered and evened by them. After the departure of the ice, the courses of the streams were determined by the position and slope of these deposits, and some discrepancy between their present and former courses was produced. The slopes of the glacial deposits in the valleys were gentle, lakes occupied the hollows more numerously than at present, and the new streams obtained steep grades only after they emerged from the hills on the slopes leading down to the Champlain and St Lawrence valleys. Their profile was convex rather than concave, and so it remains to a large extent today, while in mature stream valleys the profile is concave.

The main streams of the region are of respectable size, and their slope is steep. The Saranac river from Lower Saranac lake to Lake Champlain, in a course of about 75 miles by the river, has a fall of over 1400 feet, nearly 20 feet to the mile. The Ausable, from Lake Placid down, has a greater fall than the Saranac

[1] U. S. Geol. Sur. 3d An. Rep't, p.362.
[2] Geol. Soc. Am. Bul. 9:191.

by 300 feet in a somewhat shorter course. The Raquette and St Regis have a slope somewhat less, but yet over 15 feet to the mile. These are considerable slopes for streams of the size, and excavation of their beds is going on at a fairly rapid rate. The drift deposits were rapidly cut into and the top of the rock knolls of the valley floors, which lay underneath the stream where it was not over its old channel, were uncovered. The rapid downcutting would be at once checked at these points, but on the downstream side of the obstruction the cutting in the drift would continue actively, causing a fall or rapid at the point, which would commence to saw back a gorge into the rock obstruction. Upstream, however, the drift could not be cut out to a greater depth than the level of the obstructing rock ledge, though it would be quickly worn down to that level and a wide valley rapidly eaten out in the yielding drift materials. In this way the stream courses would be divided into sections of slight declivity and of mature character, commencing and terminating with rapids over rock ridges.

Most of the Adirondack streams illustrate well these general principles. Their head waters are in chains of lakes, and their courses below consist of reaches, or stillwaters or levels as they are locally called, interrupted by rapids and gorges. The Saranac serves well as a type. It rises in Lake Clear, passes thence into Upper Saranac lake, Round lake and Lower Saranac lake and leaves the latter near the middle of its eastern side in a wholly postglacial channel. At the rapids at Saranac village the river is only 6 miles distant from Lake Clear in an air line, while by water it is from 25 to 30 miles distant. Below the village the first considerable rapid is at Franklin Falls some 20 miles away, where the river falls 40 feet within the space of half a mile. In the 20 miles above it has fallen less than 100 feet, or only about 4 feet a mile. Below the falls it flows through a gorge half a mile long, with walls 100 feet high, which apparently marks the channel of a small preglacial stream, or else a low divide between two small streams. Below the gorge a wide marshy valley opens out, through which the river flows in a beautiful series of meanders. Heavy drift filling turns it aside over the rock ledge in the gap at Union Falls. At Clayburg, 8 miles below, it meets the north branch and turns abruptly into the larger valley occupied by

that smaller stream. Turned aside, probably by depth of drift, the river encounters the ponderous rock ridge at the High falls, in which it has cut a very considerable gorge, which appears wholly postglacial. The position of the preglacial channel hereabout has not been ascertained, a fairly continuous line of rock outcrops occurring to the northward and many appearing to the south of the present channel.

Beyond the High falls the valley is again broad and filled with drift. At Cadyville the river is once more out of its old channel, and has cut quite a gorge in the Potsdam sandstone at that point. From Cadyville to the mouth of the river at Plattsburg the fall is 400 feet and the distance 10 miles, giving a rate double the average fall of the stream, yet the bottom of the drift filling is nowhere reached save at the pulp mill, 2 miles above Plattsburg, where a long but not deep cut through the Beekmantown limestones has been made, and at Plattsburg itself.

Two thirds of the 1400 foot fall of the Saranac is made in the lower one third of its course, giving a highly convex profile. The Ausable follows its old valley more closely, crosses the 1000 foot contour much farther from its mouth and has a profile not notably convex. The northwesterly streams all have convex profiles also.

The Raquette drainage shows some interesting and puzzling features. The reach from Raquette falls to Piercefield is much the longest shown by any Adirondack stream. In all this distance the valley is wide and mature, the river flows in great loops which reach the rock walls but seldom, cut-off oxbows are exceedingly common, and the valley floor is mainly one great swamp. The valley narrows to Raquette falls, where there is a fall of 70 to 80 feet in a gorge ¾ of a mile long, in which the water is rapid throughout, but with two principal falls [pl. 18]. There is an impassable rock barrier here, with no opportunity for a buried channel, so that there could have been no preglacial drainage line; rather, there was here a col between small streams flowing both ways from the obstruction. Above Raquette falls the valley widens southward, as it should on this supposition. It was occupied by a small preglacial, south flowing stream, which either

Plate 18

Main fall in the gorge at Raquette Falls. The rock is the border, gabbroid phase of the anorthosite

turned eastward into the valley running east from Long Lake village, or else westward and out through Raquette lake valley and the Moose river. The former is the more likely, though the drainage must originally have been westward, and this eastward course represents a later reversal of direction, since it crosses the main axis.

The stream flowing north from Raquette falls was a tributary to the main drainage line running westward from Axton, in the present Raquette valley, with the Ampersand creek valley as its eastward extension. Not unlikely there was a corresponding tributary from the north, occupying the present valley of Upper Saranac lake, though it is not yet certain whether that stream drained to the south into the Raquette or to the north into the St Regis. The general drainage arrangement in this district is of the trellis pattern, it being a northern extension of the southeastern area, where that type prevails, though it seems more disturbed by glacial action than that.

Lakes

Lakes are of frequent occurrence throughout the Adirondack region. They most abound in what has been called the lake belt, but they are found in great number throughout the central and western portions of the region. East of the main axis, they occur in much smaller number, though by no means infrequent. There are literally hundreds of them. They range in size from fairly large bodies of water, several miles long and a mile or two in width, down to the most insignificant of ponds. The larger ones are usually long and narrow and occupy the full width of the valley in which they lie. These are mostly confined to the central and eastern portions of the district, those portions whose main valleys have received a north to northeast alinement from the faults, and the lakes occupy portions of the main valleys, their trend coinciding with that of the valley direction. Upper and Lower Saranac, Big and Little Tupper, Indian, Schroon and Long lakes are the more prominent members of this group. Placid, Cranberry and Raquette lakes are of a somewhat different

type, in that they seem to occupy portions of more than one valley, the valleys being closely adjacent and the divides low, and their greater breadth being thus accounted for. There are rock islands, in fact, in all of these large lakes and often in considerable number. Lower Saranac lake is full of them, alined so as to suggest the drowning of adjacent small valleys. The chain of islands in the center of Big Tupper lake suggests the same thing.

The smaller lakes are of a great variety of types. Some of them are in narrow and some in wide valleys; some are nearly or wholly rock bound, while others show little or no rock along their shores; some are in deep, steep sided valleys, while others have low, sloping shores; some are strung out in chains along a single valley, though the majority are single.

The causes for the existence of these lakes are as various as the causes which produce hollows on the surface of a region recently invaded by an ice sheet, such a surface having a combination topography due to both destructive and constructive processes. It is held by many observers that locally glaciers may excavate shallow rock basins, and Ogilvie has argued that lake basins of that type are abundant in Hamilton county.[1] Quite likely also such exist in the north portion of the region, though they certainly are not the common type there, the majority occupying depressions in the drift surface in the wider valleys. Such a lake as that shown in plate 16, for example, is a good representative of the usual type. This lake, Stony Creek pond, shows occasional rock ledges on its east shores, but it lies on the east edge of a great sand terrace which extends from the south end of Upper Saranac lake to Axton on the Raquette, the sand undoubtedly overlying till at no great depth, so that we are dealing with a small preglacial valley now badly clogged with drift. The level of the pond is so nearly that of the modern Raquette at Axton that its outlet has no cutting power.

The larger lakes are mostly up near the main divide of the region; and, though they occupy portions of preglacial valleys, these were toward the head waters of the preglacial streams and were therefore of no great width. Their south to southwest

[1] *Op. cit.*, p.411.

trend closely conforms to the direction of movement of the ice sheet, which must thus have thoroughly scoured them, and it may well be that some, or all, of them have somewhat of the rock basin character, though no proof of this is yet at hand, so far as the writer is aware. Many of them are demonstrably held up by morainic dams; but that might be true and yet the lake be somewhat of the rock basin type. Many have highly irregular shore lines, owing to the drowning of the mouths of the small, tributary valleys, and in general there are no features of these which at all suggest the hanging valley type; they rather strongly suggest the contrary. In the comparatively small number of instances of what may prove to be hanging valleys, of which Bog river falls at the upper end of Big Tupper lake is a good example, it is far from certain that the streams are not locally out of their preglacial channels near their mouths, and that the fall is not thus to be accounted for. There are however some features of these larger lakes that do suggest some deepening of their basins by the ice sheet, but the data are too fragmentary to justify a present discussion.

Many of the Adirondack lakes are being shallowed quite rapidly by the considerable amount of sediment washed into them by the streams. In the few thousand years that have passed since the ice vanished from the region quite a number of lakes, both large and small, have been completely filled in this way and converted into vleis. And at the present day many examples showing all stages of the process are to be found.[1] Some are converted into comparatively dry meadows, some are wet and boggy, some have still a foot or so of water, but with a growth of vegetation over the entire surface, others have still some clear water in the center, others only a fringe of rushes and water lilies along their margins, still others are very shallow throughout but with only a beginning of vegetable growth, and this well out in the pond as well as near shore, yet others are still comparatively deep. Almost without exception the topographic sheets of the region show examples, and often numerously. On the Saranac lake quadrangle, for example, a filled lake basin, 4 miles long, is seen in the north center of the sheet,

[1] *See* Smyth, C. H. jr. Lake Filling in the Adirondack Region. Am. Geol. 11:85–90.

its flat surface being utilized by the Chateaugay Railroad for a roadbed, while Sumner creek works its sluggish way through it in a beautifully typical, meandering course; Ray brook may be seen flowing through a small, filled pond on the southeastern part of the map; on the extreme southwest, the marsh which fills the former east portion of Middle Saranac, locally called Round lake, is well shown; on the northwest, the Osgood river flows into the pond of the same name through a swamp which marks its filled northern extension; the south end of Colby pond is converted into a marsh; on the other hand, Lower Saranac and Rainbow lakes, Mackenzie, Moose and Lonesome ponds are not yet sufficiently shallowed anywhere to show more than a mere beginning of marsh vegetation. On the Blue mountain quadrangle there are fewer examples, but Polliwog pond, on the extreme north and just east of Long lake, is marsh except for the small lagoon yet remaining in the center; Rock lake is marsh at the west; and the Grassy ponds, on the east near the Chain lakes, have names which imply their condition. These are but two examples selected at random from among the 20 Adirondack sheets so far published. Any of the remainder would have served equally well. Those lakes originally the shallowest, and those into which sediment is being, or has been washed the most rapidly, are of course those in the most advanced stage.

According to Ries, while lake filling is going on at many points in the Adirondack region, yet very little true peat seems to have been formed, for the streams flowing into the lakes often carry too much sediment, and plants other than mosses usually fill up the lake.[1]

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[1] N. Y. State Geol. 21st An. Rep't. 1903. p.r85.

INDEX

The superior figures tell the exact place on the page in ninths, e. g. 331^3 means page 331, beginning in the third ninth of the page, i. e. about one third of the way down.

Adamellite, analyses, 339^7.
Adams, F. D., cited, 305^9, 343^4, 345^1.
Adirondack eruptives, general characters, 338^5-40^7.
Akerite, 340^1.
Albite, 313^7, 319^5, 334^4, 335^7, 336^3, 337^2, 339^9, 348^6, 352^4, 352^5.
Allanite, 313^6.
Alnoite, 398^4.
Ami, cited, 383^5.
Amphibolites, 296^5, 301^1, 301^6, 330^7.
Analcite, 396^7.
Analyses, 331^3-38^5, 350^5-51^4, 397^6, 398^6-99^4.
Andesin, 320^3, 321^4, 328^6, 349^2, 396^2.
Anorthite, 304^4, 328^6, 334^4, 335^7, 336^3, 337^2.
Anorthoclase, 352^7.
Anorthosite, 275^8, 303^3-8^6, 338^7, 340^5, 341^2; analyses, 332^6, 334^7; differentiation, 305^9-7^6; relation to syenite, 318^9-22^5; surrounding rocks, 307^7-8^6; texture, 305^3; Whiteface type of, 310^6-12^1.
Anorthosite gabbros, 306^7, 308^9, 310^5, 310^8, 320^3; analyses, 332^7, 334^8.
Anorthosite outliers, 308^6-10^5.
Apatite, 295^5, 304^5, 309^5, 309^8, 309^9, 311^6, 313^5, 313^8, 319^4, 326^3, 329^6, 335^8, 348^6, 351^7, 352^4, 352^5, 352^7, 398^3.
Appalachian uplift, 421^8-23^4.
Asaphus canalis, 366^9.
Augite, 300^7, 304^5, 305^1, 309^7, 309^9, 310^1, 311^5, 313^5, 313^6, 313^8, 313^9, 319^4, 328^3, 328^7, 329^3, 329^4, 334^4, 335^8, 336^4, 337^2, 337^5, 349^2, 349^4, 349^6, 349^9, 350^4, 351^6, 351^8, 351^9, 396^2, 396^7.
Augite syenite, 340^1; analyses, 333^1, 339^7, 353^5.
Ausable river, 439^5, 440^4, 442^9.

Banatite, analyses, 339^7.
Basic dikes, 396^2.
Batholites, 402^2.
Beekmantown (Calciferous) formation, 281^2-82^7, 360^7-69^3, 388^3-89^9.
Big Chazy river, 440^4.
Biotite, 296^5, 300^3, 300^8, 304^6, 309^3, 313^6, 315^2, 318^6, 319^4, 323^6, 328^9, 348^4, 348^6, 349^7, 351^7, 352^4, 352^6, 396^2, 396^7, 398^2.
Birdseye limestone, *see* Lowville (Birdseye) limestone.
Black creek, 442^3.
Black river, 438^3.
Black river formation, 283^9-84^6, 371^5-73^4, 391^8-93^2; thickness, 376^5.
Bolboporites americanus, 366^4.
Bostonites, 395^5-96^1.
Brainard, cited, 361^2, 365^4, 374^8, 376^4, 383^4.
Brigham, cited, 437^9, 438^4, 438^7, 440^6, 442^2.
Brögger, cited, 340^9.
Bronzite, 305^2, 313^5, 337^5, 349^5.
Bucania *sp.*, 367^4.
Bytownite, 304^4.

Calciferous formation, *see* Beekmantown (Calciferous) formation.
Calcite, 348^7, 395^8.
Calymmene multicosta, 367^3.
Cambric sandstone, *see* Potsdam (Cambric) sandstone.
Camerella (?) costata, 365^8.
Campbell, cited, 424^9.

Camptonites, 396^2.
Cassin formation, 362^7-64^9.
Cenozoic history, 290^7-92^8.
Chalcopyrite, 304^6.
Chamberlin, cited, 441^9.
Champlain dikes, age of, 396^9-97^5.
Champlain valley, 438^3.
Chazy formation, 282^7-83^4, 365^1, 389^9-90^9.
Cheirurus polydorus, 366^9.
Chemical analyses, 331^3-38^5, 350^5-51^4, 397^6, 398^6-99^4.
Chlorite, 304^7, 348^7, 351^9, 352^7.
Cumings, cited, 377^8, 383^7.
Cushing, H. P., cited, 374^9.

Dannemora formation, 303^1.
Darton, cited, 397^8, 410^2.
Diabase, 278^9, 348^9-54^2, 355^7, 356^2; analyses, 351^1, 353^5.
Diabase dikes, 345^7, 346^6, 348^9-54^2; faulting, 403^8.
Diana syenite belt, 315^4.
Dikes, 278^7, 345^6; black, 279^2; diabase, 345^7, 346^6, 348^9-54^2, 403^8; red, 279^1; syenite, 346^7. *See also* Basic dikes; Champlain dikes.
Drainage, 437^6-45^5; present, youthful character of, 442^5-45^5.

Eakle, cited, 351^9.
Elevation, main axis of, 427^2-29^2.
Emmons, cited, 369^9, 372^8, 380^5.
English river, 440^4.
Enstatite, 300^7.
Epidote, 304^7, 348^7, 351^9.
Erosion, paleozoic, 288^6-89^2.
Erosion interval, surface topography at close of, 277^4.

Faults, 403^5-12^1; crossing Appalachian uplift, 422^1; production of, 286^6; as topographic features, 430^2-33^2.
Feldspar, 295^9, 297^3, 299^9, 300^7, 301^1, 304^4, 304^7, 309^2, 309^7, 309^9, 313^1, 313^5, 313^7, 319^4, 319^5, 320^6, 321^4, 326^7, 328^3, 328^8, 329^7, 334^4, 336^4, 337^3, 337^8, 338^7, 339^8, 348^3, 348^6, 349^2, 349^4, 349^9, 351^8, 352^2, 352^4, 352^5, 352^7, 354^7, 354^9, 355^2, 356^2, 356^7, 395^6, 396^2; white, 311^1.
Folds, 402^6-3^4.
Foliation, 399^9-402^5.
Fourchites, 396^2.

Gabbros, 275^8, 306^7, 327^8-31^3, 335^9, 338^7, 340^5; analyses, 332^7, 353^4.
Garnet, 295^8, 296^2, 304^6, 306^4, 309^1, 309^8, 311^6, 313^5, 313^6, 314^1, 319^4, 328^9, 334^4, 335^8, 337^1, 337^5, 337^8, 354^8
Geologic history, summary of, 272^7-94^5.
Glacial history, 292^8-93^8.
Gneisses, 273^3, 294^9, 295^7, 338^2, 343^1, 356^5; analyses, 333^3; doubtful, 299^6-303^3.
Granites, 275^8, 322^5-27^8, 338^6, 338^9; foliation, 401^4.
Graphite, 295^4, 295^8, 296^8.
Grasse river, 439^1.
Grenville rocks, 295^4-99^5, 435^3.

Harpes *sp.*, 366^9.
antiquatus, 366^2.
ottawaensis, 366^2.
Helderberg submergence, 386^2.
Hematite, 348^6, 348^7, 352^6, 352^7 356^7, 395^7.
Hornblende, 296^5, 300^2, 300^8, 301^1, 304^6, 309^7, 309^8, 309^9, 310^1, 311^4, 313^5, 314^1, 314^9, 315^8, 319^4, 323^6, 326^7, 328^9, 329^3, 330^7, 334^4, 335^8, 336^4, 337^5, 337^7, 348^6, 352^5, 396^2, 396^7.
Hoskins, L. M., cited, 401^9.
Hudson river, 439^5, 441^6.
Hyperite, 330^7; analyses, 332^6, 353^4.
Hypersthene, 300^7, 304^5, 305^2, 309^7, 309^9, 312^9, 313^5, 313^6, 313^9, 319^4, 328^3, 329^3.

Igneous activity, 287^7-88^5.
Igneous intrusions, 275^4.
Igneous rocks, 274^1; foliation, 400^7; paleozoic, 394^8-99^4; late Precambric, 345^5-54^2; of the upper Mohawk region, 397^8-98^5.

Illaenus arcturus, 366^2.
bayfieldi, 366^2.
incertus, 366^2.
Ilmenite, 304^5, 304^8, 305^2, 309^8, 328^5.
Intrusives, metamorphosed condition of, 340^8-45^5.
Iron ores, 311^6.

Joints, 404^4, 412^1-16^6; production of, 286^6.

Kaolin, 395^8.
Kemp, J. F., cited, 297^4, 298^7, 306^7, 308^8, 310^6, 314^7, 317^3, 317^5, 329^9, 330^6, 346^2, 349^1, 349^8, 350^5, 393^3, 395^1, 395^3, 395^9, 396^9, 397^6, 397^8, 398^4, 405^1, 415^6; acknowledgments to, 271^4.
Kolderup, cited, 339^1.

Labradorite, 304^4, 304^7, 309^7, 311^5, 328^3, 328^6, 329^3, 329^4, 334^7, 335^3, 335^5, 336^4, 341^9, 349^2, 351^6, 396^2.
Lake belt, 429^2-30^2.
Lakes, 445^5-48^7.
Leeds, cited, 351^8.
Leptaena fasciata, 366^8.
Lichas minganensis, 366^9.
Limestones, 273^8, 295^4.
Limonite, 395^8.
Lingula huronensis, 366^2.
Little Falls fault, 431^5.
Lorraine formation, 384^8-86^1.
Lowville (Birdseye) limestone, 283^5, 369^4-71^4, 391^1.

Maclurea magna, 366^5, 366^6, 367^1.
Magnetite, 300^2, 300^8, 313^5, 319^4, 325^4, 326^7, 328^3, 328^5, 328^8, 334^4, 335^7, 336^3, 337^2, 348^6, 349^2, 351^7, 352^4, 352^5, 354^8, 355^2, 356^3, 396^6, 398^2; titaniferous, 304^5, 306^7.
Melilite, 398^2.
Mesozoic base-leveling, 423^4-25^2.
Mesozoic history, 289^3-90^6.
Metamorphosed condition of the intrusives, 340^8-45^5.
Microcline, 299^9, 300^2, 348^6, 356^3.
Microperthite, 297^4, 299^9, 300^2, 304^6, 313^5, 313^6, 313^7, 313^8, 319^5, 320^3, 321^4, 326^7, 336^4, 338^7, 339^3, 348^6, 352^4, 352^5, 352^7, 356^3.
Mohawk river, 438^3.
Mohawk valley, faults, 410^2, 431^1.
Monadnocks, 426^3, 427^6.
Monchiquites, 396^2.
Monticulipora, 367^4.
Monzonite, analyses, 339^6.
Morris granite, 326^5-27^8.
Muscovite, 304^7, 348^7.

Norite, analyses, 332^6, 334^8.
North plain, 433^2-34^4.
Northern hills and valleys, 434^4-37^5.

Ogilvie, cited, 437^9, 440^7, 446^5.
Oligoclase, 304^6, 313^6, 339^9.
Olivin, 328^3, 349^2, 349^5, 351^7, 396^2, 396^7, 398^2.
Olivin diabase, analyses, 351^3.
Ophicalcite, 295^7.
Orthis *sp.*, 365^9, 366^7.
costalis, 366^1.
disparilis, 367^2.
perveta, 366^8, 367^1.
platys, 366^8.
porcia, 367^1.
Orthoceras *sp.*, 365^9, 366^7, 367^3.
Orthoclase, 300^2, 313^8, 334^4, 335^7, 336^3, 337^2, 348^6, 352^8.
Orton, cited, 364^6, 380^8, 384^3, 388^6.
Oswegatchie river, 439^1.
Ottawa gneiss, 302^3.
Ouachitite, 396^3.

Paleocystites tenuiradiatus, 366^3.
Paleozoic changes of level, 285^2-86^2.
Paleozoic disturbances, 286^2-87^7.
Paleozoic erosion, 288^6-89^2.
Paleozoic faults, 405^6-12^1.
Paleozoic history, early, 279^4-85^2.
Paleozoic igneous activity, 287^7-88^5.
Paleozoic igneous rocks, 394^8-99^4.
Paleozoic oscillations of level, early, summary of, 386^9-94^7.
Paleozoic rocks, 354^2-99^5.

Paleozoic topography, 419^{8}-21^{8}.
Peneplains, 417^{8}, 425^{2}-27^{2}.
Perkins, cited, 375^{5}, 376^{1}.
Perovskite, 398^{2}.
Phlogopite, 295^{5}, 296^{5}.
Placoparia (Calymmene) multicosta, 367^{3}.
Plagioclase, 329^{8}, 336^{4}.
Pleonaste, 329^{6}.
Porphyry, 355^{7}; syenite, 348^{3}.
Postglacial history, 293^{8}-94^{5}.
Potsdam formation, 279^{9}-81^{1}, 354^{2}-60^{7}, 387^{1}-88^{7}; thickness, 358^{5}.
Precambric disturbances, later, 278^{1}.
Precambric erosion, 276^{8}-77^{4}.
Precambric faulting, 403^{5}-5^{5}.
Precambric history, 273^{2}-79^{3}.
Precambric igneous activity, 278^{4}-79^{3}.
Precambric igneous rocks, late, 345^{5}-54^{2}.
Precambric rocks, 294^{6}-354^{2}; foliation, 399^{9}-402^{5}; joints, 404^{4}.
Prepotsdam topography, 418^{2}-19^{8}.
Prosser, cited, 363^{7}, 372^{1}, 372^{3}, 373^{4}, 377^{3}, 377^{8}, 378^{6}, 379^{4}, 384^{5}, 392^{2}, 411^{3}.
Pyrite, 295^{8}, 304^{6}, 309^{8}, 313^{6}, 319^{5}, 329^{6}.
Pyroxenes, 295^{5}, 295^{8}, 296^{4}, 300^{7}, 301^{3}, 305^{1}, 309^{9}, 311^{4}, 314^{9}, 315^{8}, 323^{5}, 328^{9}, 330^{7}, 337^{7}, 349^{5}, 398^{2}.
Pyrrhotite, 304^{6}, 309^{8}, 329^{6}.

Quartz, 295^{5}, 297^{3}, 300^{2}, 304^{6}, 309^{7}, 309^{8}, 309^{9}, 311^{6}, 313^{5}, 313^{6}, 313^{8}, 314^{2}, 319^{4}, 321^{4}, 323^{5}, 326^{7}, 328^{9}, 334^{4}, 335^{8}, 337^{2}, 338^{1}, 338^{6}, 348^{6}, 352^{5}, 352^{6}, 352^{7}, 355^{2}, 356^{1}, 356^{7}, 395^{6}, 395^{8}.
Quartz augite syenite, 340^{1}; analyses, 333^{5}, 339^{7}, 353^{5}.
Quartz norite, analyses, 334^{8}.
Quartz syenite porphyry, analyses, 353^{5}.

Raquette river, 439^{1}, 443^{1}, 444^{6}.
Rhynchonella plena, 367^{4}.
Ridges, northern, 434^{5}.
Ries, Heinrich, cited, 448^{6}.
Rock structures, 399^{5}-416^{6}.
Rome river, 442^{2}.
Ruedemann, Rudolf, cited, 393^{9}.

Sacandaga river, 439^{5}, 441^{6}.
St Lawrence valley, 438^{4}.
St Regis river, 439^{1}, 443^{1}.
Saranac formation, 299^{6}-303^{3}.
Saranac river, 439^{6}, 440^{4}, 442^{9}, 443^{6}.
Scapolite, 295^{5}, 304^{7}, 329^{6}, 352^{2}.
Schists, 273^{8}, 295^{7}.
Schroon river, 439^{5}.
Scolitus minutus, 361^{8}.
Seeley, cited, 361^{2}, 365^{4}, 374^{8}, 376^{4}, 383^{4}.
Serpentine rocks, 295^{6}.
Sillimanite, 295^{8}, 296^{3}.
Smyth, C. H. jr, cited, 302^{3}, 315^{4}, 316^{3}, 317^{5}, 329^{9}, 330^{6}, 346^{4}, 388^{3}, 397^{8}, 398^{3}, 447^{9}; acknowledgments to, 271^{6}.
Solenopora compacta, 367^{3}.
Sphaerexochus parvus, 366^{9}.
Spinel, 329^{6}.
Stenopora, 367^{5}.
Streams, 437^{6}-45^{5}.
Strophomena *sp.*, 366^{7}.
incrassata, 367^{2}.
Syenite porphyries, 348^{3}, 354^{1}, 355^{7}; analyses, 351^{8}, 353^{5}.
Syenites, 275^{8}, 312^{2}-22^{5}, 338^{9}, 340^{4}, 346^{7}; analyses, 333^{1}, 336^{5}, 339^{6}; amount of differentiation of, 325^{3}-26^{4}; granitic phase of, 323^{3}-25^{3}; mineral composition, 313^{4}-14^{4}; other areas, 316^{9}-18^{9}; relation to anorthosite, 318^{9}-22^{5}; variability of, 314^{4}-16^{9}.

Titanite, 309^{8}, 311^{6}, 313^{6}, 313^{8}, 319^{4}, 329^{6}, 348^{7}, 356^{3}.
Titanium, 353^{6}.
Topography, 416^{7}-48^{8}; at close of erosion interval, 277^{4}; paleozoic, 419^{8}-21^{8}; Prepotsdam, 418^{2}-19^{8}.
Tornebohm, cited, 330^{7}.
Trachytes, 395^{5}-96^{1}.
Tracy brook fault, 431^{9}.
Trenton formation, 283^{9}-84^{6}, 373^{4}-82^{8}, 393^{2}; thickness, 376^{4}.

Utica formation, 284^6-85^2, 382^3-84^7, 393^8-94^5.

Valleys, northern, 434^5.
Van Hise, cited, 345^2.
van Ingen, cited, 354^6, 357^3, 358^6, 359^1, 359^6, 388^9.
Vanuxem, cited, 373^4.

Walcott, cited, 358^6, 359^6, 360^5, 383^4, 383^8, 384^2, 385^3, 388^6.
West Canada creek, 442^2.
Westgate, cited, 438^4.
White, T. G., cited, 371^7, 372^6, 373^9, 374^8, 375^9, 376^5, 379^2, 379^4, 383^3.
Whitfield, cited, 362^3.
Williams, G. H., cited, 397^8.
Winchell, N. H., cited, 360^1.
Woodworth, J. B., work of, 272^5, 437^9.

Zircons, 309^8, 309^9, 311^6, 313^5, 313^8, 319^4, 326^3, 337^9, 354^8.
Zoisite, 304^7.

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Bulletin 96

GEOLOGY 10

GEOLOGY

OF THE

PARADOX LAKE QUADRANGLE, NEW YORK

BY

IDA H. OGILVIE

	PAGE
Introduction	461
Topography and geology of the Adirondacks	461
Recent geologic work	463
Location and topography of the Paradox Lake quadrangle	464
Physiography and glaciology	465
Cambric drainage lines	465
Peneplains	468
Summary of the preglacial erosion history	468
Age of lower base-level	469
Glacial deposits and drainage modifications	469
General geology	478
Summary of evidence of relative age of igneous rocks	487
Petrography	492
Petrography of sedimentary rocks	493
Petrography of igneous rocks	495
Summary and conclusions	502
Economic geology	503
Index	507

State Museum, Albany N. Y. Oct. 25, 1904

Hon. Andrew S. Draper

State Commissioner of Education

SIR: I beg to transmit for publication as a bulletin of the State Museum a paper by Dr Ida H. Ogilvie on *The Geology of the Paradox Lake Quadrangle.*

Very respectfully yours

JOHN M. CLARKE

Director of Science

State of New York

Education Department

COMMISSIONER'S ROOM

Approved for publication Oct. 27, 1904

A. S. Draper

Commissioner of Education

New York State Museum

JOHN M. CLARKE Director

Bulletin 96

GEOLOGY 10

THE GEOLOGY OF THE PARADOX LAKE QUADRANGLE, NEW YORK

PART 1

INTRODUCTION

The field work upon which this paper is based was carried on during the summer of 1901. The results were elaborated in the laboratories of Columbia University during the winter of 1901–2, and in the summer of 1902 a general survey was made embracing the surrounding region beyond the limits of the report proper, together with a resurvey of certain critical points within the area in question. The work was directed by Prof. J. F. Kemp of Columbia University, to whom the most cordial thanks are due, and whose kindly interest both in field and laboratory has been of constant value.

TOPOGRAPHY AND GEOLOGY OF THE ADIRONDACKS

The Adirondacks form the most conspicuous topographic feature of northern New York. They include an area of some 10,000 square miles, roughly circular in outline, and almost surrounded by the St Lawrence, the Mohawk and the Hudson-Champlain valleys. Topographically the region may be divided into a central mass of high peaks with deep and narrow intervening valleys, and a surrounding area of lower hills with broader valleys and gentler slopes. Geologically the central mass consists of plutonic rocks of the gabbro family; the surrounding hills, of various types of gneiss. In the gneissic area limestone prevails in the valleys, and the limestone often extends up the valleys of the central plutonic core. Surround-

ing the crystalline area and outside of the Adirondacks proper is a plain cut on gently dipping Palaeozoic rocks. A few outlines of these Palaeozoics within the crystalline area indicate their former extent.

The Adirondack region has been extensively faulted. Some of these faults are quite recent (though all are preglacial) and form conspicuous topographic features. The most recent faults run in general northeast-southwest directions, and were accompanied by block tilting toward the east. Drainage lines have established themselves along the fault lines, the tributaries on opposite sides working against a steep cliff or a gentle slope respectively.

The trellised drainage of the Adirondacks has been noted by Professor Brigham.[1]

He showed from a study of several topographic maps that the main drainage lines lay along northeast-southwest valleys, and that of the tributaries, the eastward flowing ones had much the longer courses. The main drainage lines lie along the fault lines, and as the tilting has been toward the southeast, the tributaries flowing in that direction have the advantage over those flowing westward, which have to cut back against the faces of steep fault cliffs.

This block tilting has led to the production of a most striking feature in the landscape, namely, the peculiar form of the mountains. The almost universal shape of the higher hills is that of a truncated cone, with steep, often precipitous faces toward the northwest and long gentle slopes toward the southeast. There are some lower summits which owe their existence to the erosion of the soft limestone from the valleys, such mountains of course presenting normal erosion outlines. But the prevailing type is the faulted one.

This general type of mountain, accompanied by this kind of drainage, is the predominant one on the Paradox Lake quadrangle, irrespective of rock type. Owl Pate, Bald Pate, Catamount and many others within the anorthosite area have this outline, while among the gneisses Knob, Bear and others show the same form. The valleys at the foot of the steep fault cliffs often contain small rock-bound lakes.

[1]Am. Geol. 1898. 21:219.

Plate 1

Fig. 1 Bear mountain from Crane pond. A fault block, with cliff facing west and flat tilted eastward. Granite gneiss

Fig. 2 View from Bear Pond mountain. Chilson lake in the foreground lies in a wide limestone valley. In the background is a narrow valley whose western side is the fault cliff of Knob mountain

In the Adirondacks the most important problems today belong to two distinct departments of geology. One series of problems is concerned with the physiography and glacial phenomena, on which no detailed work has been hitherto done; the other series of problems are concerned with the gneisses, both as to relative age and as to origin.

Recent geologic work

The first geologic report on the Adirondacks was that of E. Emmons in 1842. Since that time little was attempted until about fifteen years ago, when Prof. J. F. Kemp took up the task of unraveling the complicated structure of the eastern part of the region, while Prof. C. H. Smyth jr in the west and Prof. H. P. Cushing in the north directed their efforts to those portions. The combined work of these three investigators has led to interesting results in the interpretation of the region as a whole.

The greater part of the region covered by the Paradox Lake quadrangle was described in a preliminary way in Professor Kemp's early reports.[1]

The southern portion of the region was treated by Professor Kemp and D. H. Newland.[2]

The preliminary work was done without the aid of good maps, and it was not thought advisable to begin detailed investigation until the United States Geological Survey sheets were published. Some of these topographic maps have recently appeared, and with one of them as a basis it was hoped that by a careful and detailed study of a relatively small area some facts might be added to those already accumulated. The purpose of this paper is to treat in detail of the geology, both glacial and deep seated, of the area covered by the Paradox Lake quadrangle, thus making a beginning of the interpretation of Adirondack glacial deposits, and a contribution to the solution of the problems of the gneisses.

[1] See Preliminary Reports on Geology of Essex County in N. Y. State Geologist An. Rept for 1893 and 1895.

[2] Preliminary Report on the Geology of Washington, Warren and parts of Hamilton County, N. Y. State Geologist An. Rept for 1897.

LOCATION AND TOPOGRAPHY OF THE PARADOX LAKE QUADRANGLE

The Paradox Lake quadrangle covers the southeastern part of the Adirondacks. It is for the most part within the gneissic area but in its northeastern portion includes some of the outlying peaks of the central plutonic area. The highest peaks in the Adirondacks rise to upwards of 5000 feet; the highest on the Paradox quadrangle is 2941, the region being thus among the foothills. The southern and eastern portions are in the gneissic area, where the mountains are still lower. Pharaoh mountain is conspicuously the highest of the gneissic peaks, and stands out as a landmark for miles. Its hight is 2557 feet.

Though the mountains are not very high, they are rugged and often very steep. The greater part of the region is an untraveled wilderness, and some parts of it are very difficult of access. The abandonment of the iron mines, which were formerly of economic importance, has led to the desertion of villages, and the region abounds in houses which are falling in ruins. One can easily travel for days through unbroken woods without meeting with a house or even a trail. Lumbering and forest fires have done their work here as elsewhere in the Adirondacks, with the result that the thick second growth has made travel difficult and outlooks few.

The drainage is in part westward, emptying into the Schroon and hence ultimately into the Hudson, and in part eastward toward Lake Champlain. The divide between these two drainage systems lies along a general north and south line, the westward drainage comprising about two thirds of the quadrangle. The most important stream is the Schroon river, which crosses the northwestern corner of the quadrangle. Its present course is for the most part over drift, some interesting terraces being displayed on the sides of its valley. Its most important tributary is the Paradox valley, which crosses the quadrangle in a southwesterly direction, joining the Schroon near the central portion of the western edge of the quadrangle.

Plate 2

Fig. 1 Hammondville N. Y.

Fig. 2 Valley of Rock Pond brook. Gentle slopes and broad valleys characteristic of the gneissic area

The drainage is well-adjusted, the principal valleys being either upon the limestone or in the depressions occasioned by block faulting. The limestone valleys are usually wider and physiographically older than the faulted valleys. This contrast is shown in plate 1, figure 2, where Chilson lake in the foreground lies in a limestone valley, while the steep face of Knob mountain marks a fault cliff which extends northward about five miles.

Glacial agencies have interrupted the last erosion cycle, hence this valley at the foot of Knob mountain is not occupied by a single stream but by three small lakes and a considerable extent of swamp, outletting westward in its middle portion. The limestone valleys are also drift-filled, but their drainage is usually not so markedly disarranged as it is in the narrower faulted valleys. Plate 3, figure 1, illustrates the condition in the wider valleys.

PART 2

PHYSIOGRAPHY AND GLACIOLOGY

Cambric drainage lines

Certain main lines of drainage were established before the close of Cambric time. These have been greatly modified by later adjustments—in addition to normal valley development, drowning, rejuvenation, faulting and glaciation entering into their history at various times—nevertheless the Cambric drainage can be made out and is in some localities remarkably similar to the present.[1]

The Lower and Middle Cambric strata are found in Vermont; only the Upper Cambric in the Adirondacks. This fact indicates that the Cambric sea advanced from the east, its progress being slow. It covered Vermont in Middle Cambric time, but did not reach the Adirondacks until the Upper Cambric.

Hence in Lower and Middle Cambric time the Adirondack region was a land area, and was consequently being worn down by streams. Prof. Kemp has shown that these Cambric streams were well adjusted to the structure, having placed their valleys on the limestone, and that these valleys had mature profiles and cross-sections.

[1] J. F. Kemp. Physiography of the Eastern Adirondacks in the Cambrian and Ordovician Periods. Geol. Soc. Am. Bul. 8:408-12.

This region of mature topography was then drowned by the advancing Potsdam sea, the valleys first and later the highlands, being covered by aqueous deposits. The Cambric strata are still horizontal or nearly so, hence their position in the valleys must be due to original deposition in depressions, and not to any kind of folding. In some instances their position may be due to faulting, but there was no evidence of such faulting in this region.

Potsdam outliers are found in three localities within the Paradox Lake quadrangle. One outlier is found on the extreme eastern edge of the map in the valley of Trout brook; a second near Chilson, outcrops in three localities, the intervening areas being drift-covered; the third two miles north of Sherman Corners.

The Trout brook outlier lies in a valley of mature cross-section, the present stream being rejuvenated and actively cutting. Were the Potsdam removed the valley would show the gentle slopes characteristic of a well established drainage line. The former extent of the Potsdam is indicated by many loose boulders south and west of the outlier.

The Chilson outliers are masked in drift, but they indicate the same thing—a mature Prepotsdam valley, drowned by the Potsdam sea.

The Sherman Corners outlier is now being cut by a vigorous post-glacial stream. The outline of the hills suggests that in this case also if Potsdam and glacial deposits were removed the valley would be mature.

The conclusion then seems inevitable that the main drainage lines were established in Prepotsdam time. The Trout brook valley, the Putnam creek valley and the valley two miles north of Sherman Corners are shown to be of Prepotsdam age by the outliers. By their similarity in stage of development the valleys of Chilson lake and of Paradox lake would appear to belong to the same period.

The Schroon valley is problematic in age and in origin. The largest valley on the quadrangle, it passes through the anorthosites with glacial terraces masking its sides. No limestone has been found in its basin, nor any Potsdam sandstone. The topography

Plate 3

Fig. 1 Chilson N. Y. Drift filled valley

Fig. 2 Paradox. Limestone valley

suggests faulting, and its direction (s. 15 w.) suggests a later origin than that of the Cambric valleys, whose direction is slightly north of east.

The invasion of the Potsdam sea from the east suggests that these Prepotsdam rivers flowed toward the east. This is further borne out by the attitude of the rock beneath the drift, so far as it is known, and by sounding in the lakes. In Goose pond, Crane pond, Pyramid lake and Chilson lake soundings showed a slightly greater depth of the rock bottom in the eastern than in the western ends. An uplift of 25 feet in the western part of the quadrangle would reverse the drainage of several important streams. The Chilson lake valley, after such an uplift, would drain eastward into Penfield pond; Goose pond would drain into Crane pond and Crane pond eastward through Rock pond to Putnam creek; Black brook would pass eastward until diverted by the Knob mountain fault. After a reconstruction of the country, and after removing all drift and replacing all faults, this easterly direction of drainage becomes universal. If the faulted face of Treadway mountain were removed Pharaoh lake would drain through a wide and now dry valley into Putnam pond.

The conclusion is that the drainage was established when Cambric time opened; that the general direction of drainage was eastward, usually northeast, occasionally southeast; that the streams at this time were adjusted to the limestone, and that the region was mature.

The alternative hypothesis, that the region was a peneplain in Cambric time and the outliers dropped by faulting, seems untenable in the light of these various lines of evidence. There is no evidence of such faults, but every indication, short of absolute proof, that the valleys containing the outliers were normal erosion valleys established on the limestone.

Of the events of later Palaeozoic time there is little evidence within this quadrangle. Abundant fragments of Calciferous and of Trenton rocks suggest that the region was entirely submerged. An outlier of the Calciferous is found at Schroon lake, but none within the limits of the Paradox Lake quadrangle.

Peneplains[1]

The even sky line of some of the mountains [pl. 4] suggests an uplifted peneplain. It is best displayed on Treadway mountain, but may also be seen on Springhill, Trumbull and several small unnamed mountains. Wherever found this flat rises slightly toward the northwest. Apparently this peneplain antedates the last period of faulting, since the eastward slopes of the fault blocks are invariably flat [pl. 4 and 5]. Since the rocks are igneous or metamorphic it is impossible to correlate beds or to restore the prefaulted surface with exactness. The fact that when developed on sedimentary gneiss these flat surfaces often cut across the bedding [pl. 4, fig. 2] is sufficient evidence of their origin from some process of down cutting. But whether one peneplain or more is represented is impossible to say until some estimate of the amount of faulting can be made. These flats are developed alike on undoubted igneous rock (Owl Pate, Bald Pate, Moose mountain) and on gneiss, possibly of sedimentary origin (Bear mountain, Skiff mountain, Knob mountain).

A second temporary base level is represented by the present valley floors. Like the older level this one is higher towards the northwest, but this second level follows the formation of the great faults.

Summary of the preglacial erosion history

In Prepotsdam time eastward flowing rivers were established on the limestone; these rivers were drowned by the Potsdam sea, and the whole country covered by the Lower Siluric. From the Siluric

[1] A peneplain, i. e., almost a plain, can best be defined in terms of a "base-level" or "graded slope." The last two terms are both used by different authorities to describe that condition of a land surface which is reached when, after erosion by streams, the slope is just sufficient to carry off the water without permitting either additional erosion or transportation. It is a plain as near sea level as river erosion can bring it, and it is a limiting condition which is approximated even if never reached. At a stage shortly preceding base-level, the surface would be a peneplain. A peneplain then is a nearly plane surface at sea level, produced by the erosion of streams. Should such a peneplain then be elevated and subjected to erosion again, evidence of it would remain in that the tops of the hills would be flat. These flat hilltops stand at about the same elevation, and the rock forming such flat topped hills may be of any kind or of any structure.

Plate 4

Fig. 1 Mountain 1 mile southeast of Crane pond. Peneplain cut on sedimentary gneiss

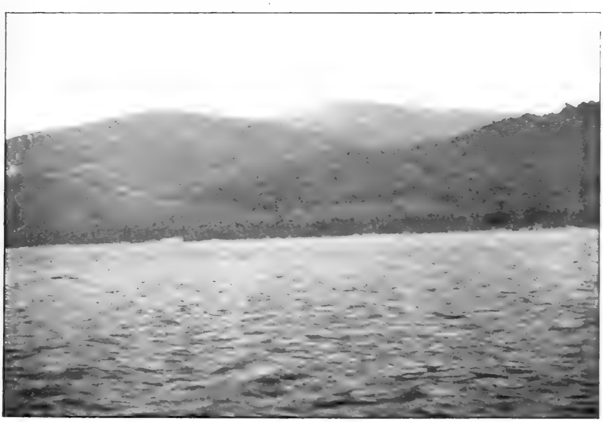

Fig. 2 Mt Treadway from Pharaoh lake. Peneplain cut across beds of dipping sedimentary gneiss

until the Pleistocene the region was a land area and of the events of this immense period of time there is very little record. Whatever the details may have been, erosion was going on, and the covering of early Palaeozoic rocks was being removed. A peneplain was finally produced.[1]

An uplift followed which was greatest in the northwest, and which was accompanied by block faulting. A new cycle of erosion began, continuing to remove the Palaeozoics from the Prepotsdam valleys, and also developing new lines of drainage adjusted to the faults. Another uplift followed, which was also greatest in the northwest. The next erosion cycle was interrupted by the glacial period. I believe that these conclusions are in a general way in accord with Dr Cushing's observations in the north.[2]

Age of lower base-level

The age of this lower level in the Adirondacks can be fixed within probable limits. The valley floor on which the drift was deposited belongs to it and the streams had just begun to incise their channels. Since therefore they had just begun to lower their channels before the glacial period, the date of rejuvenation must have been late Pliocene. If the rejuvenation of them closed the Pliocene, the cutting of the lower level must have taken place in the earlier Pliocene and Miocene.

Glacial deposits and drainage modifications

When the ice entered the region it encountered a drainage long established and well-adjusted, but physiographically young in that the region had recently been rejuvenated. After its withdrawal it left the valleys completely drift-filled and the courses of the rapidly cutting streams determined by the slope of the drift.

The glacial deposits in this area are divisible into two groups; those of unassorted material, consisting of heterogeneous mixtures of all sizes of constituents from large boulders to fine sand, with occasional admixture of clay; and those composed of fine gravel,

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[1] Analogy with other regions would suggest Cretaceous age for this first base level and Tertiary for the second, but no evidence of the age was found within the region itself.

[2] Geology of Franklin County. N. Y. State Geologist 18th An. Rept 1899.

sand, or silt, with a stratified structure. The first class comprises what is generally known as till, and as boulder clay, and is generally sprinkled over the surface. The stratified deposits overlie the thin till covering, but the two were probably laid down contemporaneously in different localities, some till being formed at the margin of the ice at the same time that aqueous deposits were gathering farther from its edge. No true moraines were found within the limits of this quadrangle. Ridges of rounded glacial hills occur in several localities, but they all proved to be of fine stratified material.

The region lay so far within the ice sheet that any deposits formed in its advance would subsequently have been removed, and the same would be true of any earlier gravels which may once have been there. The surviving deposits belong to the time of retreat and melting of the ice, at the close of its last invasion.

The erosion history and glacial phenomena of the Adirondacks as a whole were summarized by the writer in a recent paper.[1] In this paper it was shown that the general direction of ice movement was toward the southwest; that the motion was vigorous among the outlying lower hills, but that among the higher mountains the ice was stagnant in the bottoms of the deep valleys, while at the time of the maximum extension of the ice sheet it passed over the tops of these filled valleys smoothing the mountain summits. It was further shown that the glacial deposits belong in general to the time of retreat and melting of the ice, being largely of stratified material.

The Paradox Lake quadrangle lies on the border between the regions exhibiting the two types of glaciation. Its northwestern part lies in the region of high peaks and deep valleys, where there is little sign of glaciation except in the smoothed tops of the mountains. The more southerly and easterly parts of the quadrangle were in the region of the southwesterly moving ice current, hence smoothed rock faces and roches moutonnées are common, as are also glacial deposits.

Crown Point. In the northeastern corner of the quadrangle, 900 feet above sea, in the valley about two miles south of Towner pond

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[1] On Glacial Phenomena in the Adirondacks, Jour. Geol. v.10 April-May, 1901.

Plate 5

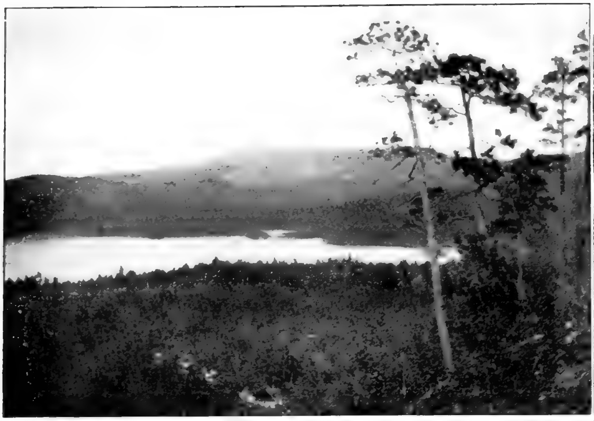

Fig. 1 Mt Treadway from Pharaoh lake. Peneplain cut on sedimentary gneiss

Fig. 2 Mt Treadway from Pharaoh lake. Peneplain cut on sedimentary gneiss

and the same distance north of Sherman Corners, is the flat bed of what was probably a small glacial lake. This lake was of short duration, not lasting long enough for the development of shore features. It was formed by the damming of a preglacial channel by the retreating ice, and its waters were supplied in part from the melting edge of the ice and in part from the eastward flowing drainage of the valley. At the margin of the ice, stratified drift hills were deposited which blocked the valley on the east after the ice had retreated. The water speedily found a new outlet farther south and the lake was drained.

At present the stream meanders over the old lake flat, having cut its channel and built a flood plain below the lake level. Its preglacial outlet is blocked by the ridge of stratified hills, and where it meets them the stream turns southward. The road to Crown Point now runs through the preglacial valley, and a branch road to the north has cut through one of the stratified hills, whose material is now being removed for gravel. In this exposure beds of coarseness varying from very fine silt to pebbles of about two inches are seen, with some cross-bedding. Farther east beyond the line of these hills typical boulder clay is found.

The stream has cut a postglacial channel around the hills that blocked its old valley, and after rounding them to the south it turns northward again, cascading over ledges of Potsdam sandstone and cutting a little canyon. The drift dam was formed at the top of a steep hill, which leads downward to Lake Champlain, and the stream descends this hill through a postglacial valley. After reaching the lower level it turns northward and reenters its preglacial valley. At the foot of the hill is another small flat which may represent another temporary lake, but its complete interpretation needs investigation beyond the limits of this quadrangle. Stratified deposits are also present along the valley leading northward from this glacial lake to Towner pond, these deposits being extensively eroded postglacially. Like the hills of the dam just described, these deposits show great variation in size of material and often cross-bedding. They were evidently formed by swift waters, and probably represent glacial outwash.

Towner pond is held up by an artificial dam sixteen feet high, the original pond being a small solution basin in the limestone at the eastern end of the present pond. The artificial dam has resulted in drowning several tributary valleys. At its principal inlet is a fall and a small natural bridge over crystalline limestone [pl. 6]. This fall is postglacial. East of the pond, surface drift is abundant, some true till being present [pl. 7]. No well data are available, but the topography suggests an eastward preglacial outlet.

The valley leading westward towards Overshot pond is filled with much drift, mainly sand and gravel. Several ridges of terminal morainic aspect are present, running in a general east and west direction. There were no cuts into these ridges. To the west, at the end of the trail, the valley broadens out in a manner abnormal for the upstream part of a small creek. A sand flat fills the bottom of this basin. No lake shore features were found about this flat; it probably represents a lake whose life was of short duration.

Ticonderoga. Three miles north of Chilson is a line of kames,[1] extending southwest for a mile and crossing the angle of the main road where it turns westward. A cut across one of these shows the material to be sand, the bedding highly inclined. Emmons in his report refers to the ridge. Immediately south of this ridge lies a swamp, its flat extending about a mile in each direction, inclosed on three sides by gneissic hills, on the fourth by the ridge of kames. Its outlet cuts across the kame belt and cascades westward through a postglacial valley into Putnam creek. The probable history of the drainage in this region is illustrated in the diagrams [fig. 1–3]. Figure 1 represents the normal river valley which would result were all Potsdam deposits, faults and glacial drift removed. Figure 2 represents the same region after the Potsdam deposits had filled the valley and the work of reexcavating had only partly followed the old channels; the basins of Putnam pond, North pond, Rock pond and Bear pond had been added by faulting. Figure 3 represents the

[1] A kame is a hill or short ridge of stratified glacial drift. Kames were formed at the edge of the ice, of material which had been transported by the ice, deposited by water issuing from the ice.

Plate 6

Inlet of Towner pond. Small natural bridge in limestone

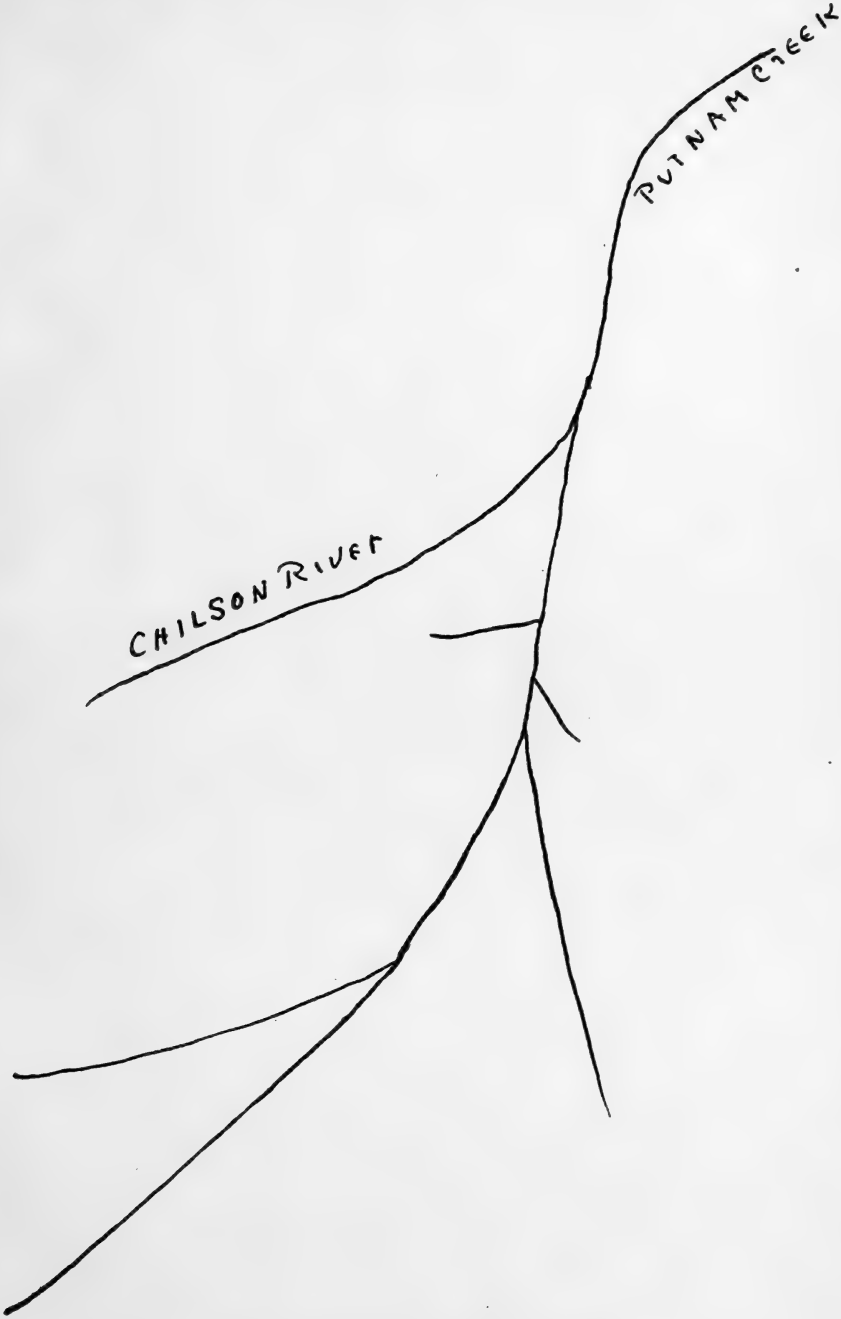

Fig. 1 Hypothetical Prepotsdam drainage

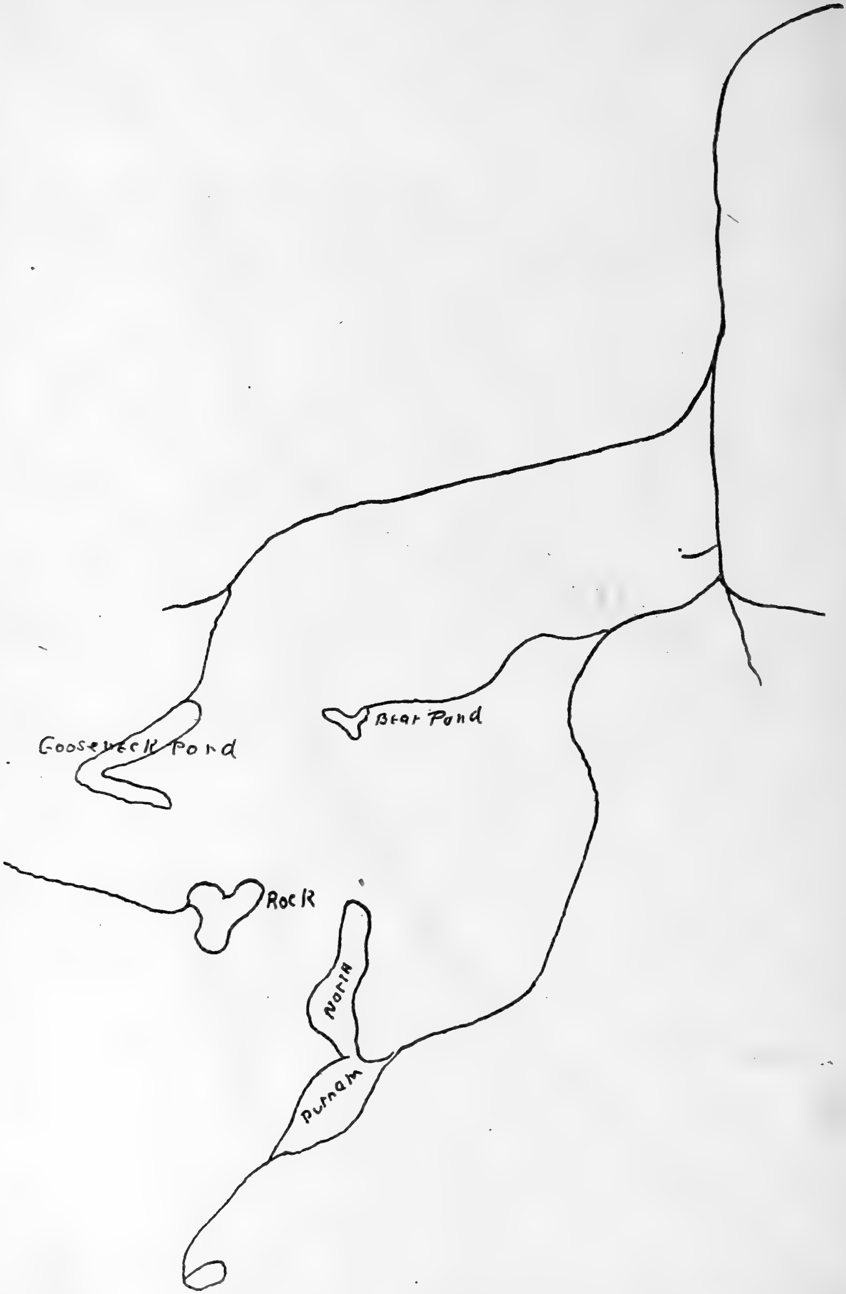

Fig. 2 Hypothetical drainage at a time later than the Siluric; later than the faulting; before the ice invasion

Plate 7

Till; south of Towner pond

present drainage, the additional lakes being caused by drift-filling or postglacial water-laid deposits, with the exception of Penfield pond, which is partly artificial. The swamp in the southwest corner

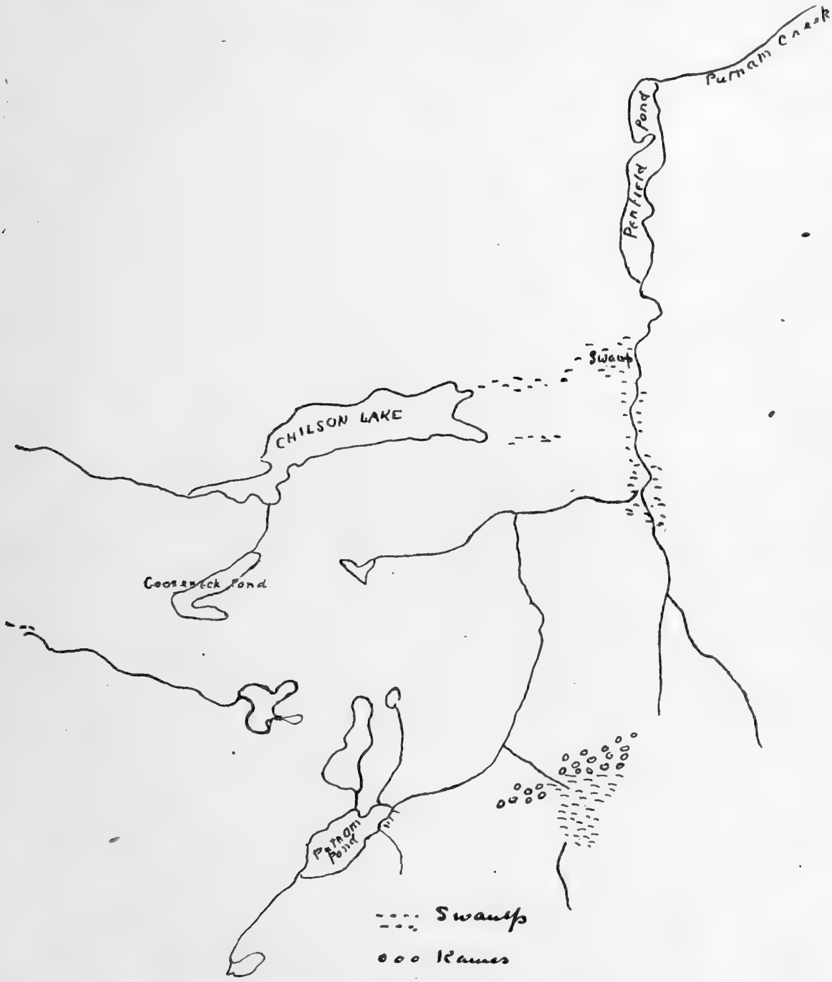

Fig. 3 Present drainage

is the one above referred to and probably represents a lake of Champlain age.

Hague. The brook in the southeastern corner of the quadrangle flows through a broad preglacial valley, now filled with rolling hills

of stratified drift. The upper course of the present stream is superimposed over this drift-covering and wanders considerably, having developed a broad flood plain in its upper course. No evidence was found of a glacial lake in this locality, the evidence pointing towards the filling of the valley by drift deposited by the escaping floods from the melting ice. Rock first appears at the bridge (one inch from the eastern end of the map) and downstream from this point the course alternates between quiet reaches, where the stream flows over drift or along the strike of the gneiss, and little cascades and rapids, where it flows southward down the dip. At the largest fall the Hague gristmill is situated, the fall in this case resulting partly from a soft, easily eroded shear-zone in the gneiss at the base of the present fall. Below this fall the stream bed is full of loose material, in part at least of postglacial origin and resulting from the cutting back near the fall. A similar fall occurs at the corner of the map.

Potholes are found at these falls, and at the one at the gristmill a little lake has been formed part way down the fall from the wearing away of a soft layer [pl. 8, fig. 1].

Trout brook also flows through an old drift-filled valley, slowly meandering in its upper course, and alternating between quiet reaches and rapids, according to whether its drift cover is or is not cut through. The rock here being massive, no such changes can be seen as in the southern brook. Close to the edge of the map Trout brook reaches the Potsdam sandstone and turns abruptly northward. It leaves an open valley only three fourths of a mile in length which leads east straight to Lake George, and turns abruptly northeast, emptying into Lake Champlain six miles away. Its lower course is on the Ticonderoga quadrangle.

This northeastward bearing valley is a very old one. Small exposures of limestone indicate that it was originally excavated upon a limestone fold. The Potsdam sandstone lies undisturbed in three localities on its lower course, suggesting that the valley existed in Cambric time and that it was drowned by the Potsdam sea. In Champlain time the valley was occupied by the water, probably of an arm of Lake Hudson–Champlain. Since the shrinkage of this

Plate 8

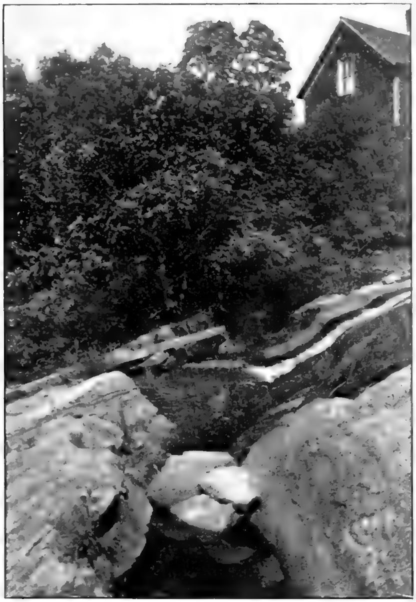

Fig. 1 Hague grist mill. Cascade down the dip of quartzite

Fig. 2 Pond in cirque, Skiff mountain

glacial lake, the lower Trout brook has reestablished itself in this old valley and has beheaded upper Trout brook whose former course was eastward, over hard gneisses.

Horicon and Schroon. Pharaoh lake and Wolf and Whortleberry ponds lie in rock basins caused by faulting. The outlets of Pharaoh lake and of Whortleberry pond join, and together are combined with Desolate brook. The junction of these three streams takes place in a broad valley filled with stratified drift.

Desolate brook is now a swamp or " vly," its still waters having been filled with sphagnum and other vegetation. The trail mapped is now impassable owing to the increasing swampy conditions.

At the northern end of Schroon lake is a wide flat extending northward for about three miles. This flat appears to be a glacial delta. At present the Schroon river meanders over its surface, and the greater portion of the flat is swampy.

Schroon and North Hudson. The Schroon river in its southwesterly course extends for about five miles within the limits of the quadrangle. On its banks are well-developed terraces.

In the course of these five miles the river descends 50 feet. Its most conspicuous terrace drops from 960 feet in the north to 930 in the south—30 foot fall in the same distance in which the present river falls 50 feet.

The surface of this terrace is slightly uneven and suggests an origin as a kame terrace, while the ice still stood in the valley. The front of this terrace has been extensively eroded, in part by the Schroon river, which has built a lower terrace of flood plain origin, and in so doing has worn back the face of the older one; in part by recent gullying. Gullies once started grow with astonishing rapidity, houses and the highways being frequently undermined. The material of this terrace is sand.

A higher terrace is to be distinguished at a few localities. This higher terrace is partly built, partly cut. It occurs 35 feet above the main terrace. Through the Schroon valley sand dunes abound, the material loosened along the gullies being blown by the wind and deposited on either of the two lower levels.

The main terrace of the Schroon extends up its tributary, Black brook.

Cirques[1] and grooves. Glacial cirques are found in at least three instances within this region. One of these is on the southern slope of Cat mountain, near the northern boundary. This cirque contains a small pond which is not on the map. A second is on the southern slope of Skiff mountain [pl. 8, fig. 2] and also contains a pond. The third is on the southwestern slope of Mount Steven; this one does not contain a lake.

On the northern shore of Paradox lake is a large glacial groove, displaying a smoothly polished surface [pl. 9, fig. 1 and 2].

Striae are rare. Those found have already been recorded.

Boulders are common, some of considerable size. These boulders are off all kinds of Adirondack rocks, Potsdam sandstone being very common.

PART 3

General geology

The crystalline rocks of the Adirondacks are part of the great series forming the Laurentides of Canada. It has never been doubted that these crystalline rocks are of Prepotsdam age.

The Potsdam sandstone lies almost undisturbed upon their eroded surfaces, and in Prepotsdam time the Precambric sediments had been tremendously folded and faulted and intruded at great depths by at least one series of plutonics. They had then been uplifted and worn down many thousands of feet until only the cores remained, and until their surfaces had attained a topography of only moderate relief. This surface had then sunk beneath the advancing Potsdam sea.

Distribution and character of formations. The crystalline complex consists in part of sedimentary rocks, lithologically identical with the Grenville series of Canada; in part of intrusives, which resemble the Norian series of Canada, and in part of other intrusives being of different character.

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[1]A cirque is an amphitheater with precipitous or very steep sides which is excavated by a glacier at its upper portion. The ice cracks off and carries away the rock from the mountain until by eating backward it leaves these precipitous walls surrounding the valley on all sides except its outlet. Cirques often contain small lakes.

Plate 9

Fig. 1 Glacial groove. North shore of Paradox lake

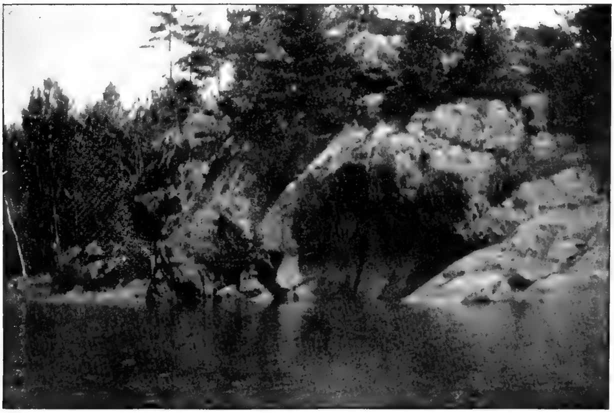


Fig. 2 Glacial groove. North shore of Paradox lake

Sediments of the Grenville series. Probably the oldest rocks on the quadrangle are metamorphosed sediments. Probably also only one series of Precambric sediments is present. Six types of sedimentary rocks are recognized: hornblende gneiss, limestone, mica schist, silimanite gneiss, graphitic quartzite, shaly quartzite.

Hornblende gneiss.[1] Typically this rock is a very quartzose hornblendic gneiss. It is of gray color. Its sedimentary origin is indicated by its large quartz content; by certain persistent streaks of brotite schist which appear to represent changes in composition which could only be explained by changes in sedimentation from sandy conditions to shaly ones; and by its vertical changes in mineral composition [*see* pl. 4, fig. 1]. The gneiss extends in a horseshoe-shaped belt through the central, southern and western portions of the quadrangle, containing within its area some of the most important mountains, namely, Treadway, Putnam, Stevens, Third Brother, Park and others. This gneiss is so excessively crushed, and also so much altered by syenites, pegmatites and quartz veins, that no structural features could be made out.

Limestone. Closely associated with the gneiss occurs crystalline limestone. It is a completely recrystallized rock, which presents such remarkable metamorphic features that it was first supposed by Emmons to be of igneous origin. Little trace of bedding is to be found. While at times almost pure, it often contains metamorphic minerals, such as graphite, apatite, pyroxene, amphibole, phlogopite, biotite, scapolite, garnet, titanite, pyrrhotite and tourmaline. Most of these minerals are clearly the result of regional metamorphism acting upon impure limestone, but some of them, notably tourmaline, titanite and scapolite, are the result of contact metamorphism. In Moriah, just north of the region covered by this map, the limestones are found charged with serpentine, forming the rock known as ophicalcite.

[1] Gneiss is a laminated metamorphic rock having the mineral composition of a granite, but not necessarily in the same proportions. Varieties are indicated by prefixing the name of the most important silicate, thus hornblende gneiss is a rock containing quartz, feldspar and hornblende.

These limestones undoubtedly represent calcareous sediments charged with magnesia, iron, silica and alumina, the latter elements forming the various silicates during metamorphism. Graphite is almost universally present.

The intense metamorphic changes which result in great contortion or complete crushing when applied to sandstone result in flowing and recrystallization when applied to limestone. The crystalline limestones of the Adirondacks have lost their original features and with recrystallization have developed polysynthetic twinning, parallel ½ R. The limestone is thoroughly crystalline throughout its extent, and its condition can not be explained as a result of contact metamorphism from the associated intrusions. Contact effects have been described by various writers in various Adirondack localities, but on the Paradox Lake quadrangle the contact metamorphism resulted in changes in the intruded rock.

The limestone is found in the wider valleys in long belts and in a few isolated patches among the hills. One long strip of it lies along the Paradox valley, while another forms the shores of Penfield pond. Gneiss and schist are often interbedded with it, and the dip can sometimes be discovered from these layers. The limestone itself is so completely recrystallized that as a rule no bedding can be made out. The only locality where a dip and strike could be determined in the pure limestone was in a little canyon on the south side of Paradox lake, where there was a little cave in the side of the cliff. Similar caves are common, and so are little natural bridges and other forms resulting from solution.

In the northwestern part of the Penfield pond limestone belt are a series of little hills of limestone interbedded with gneiss. Near Dudley pond the outcrop of alternating gneiss and limestone is repeated by a fault, the beds here dipping gently east. Farther south the limestone becomes purer; its associated gneiss stands out as several good sized hills, and no interbedding is seen.

Mica schist.[1] Typically a biotite schist, containing occasionally a little hornblende, and sometimes grading into a gneiss this rock

[1] Schists differ from gneisses in that they have finer laminations. They often have the same mineral composition as the gneisses, but sometimes are more basic. They are classified according to the principal dark silicate present.

Plate 10

Trap dike in gneiss, north shore of Pharaoh lake. The trap weathers more readily than the gneiss

invariably accompanies the sedimentary gneiss and the limestone. It occurs in bands interbedded with limestone or gneiss, the bands varying from a few inches to some feet in thickness. They are never of sufficient size to be mapped separately.

The association of limestone with schist and with banded gneiss has frequently been noted in the Adirondacks. In the Paradox Lake quadrangle the rocks were so involved and exposures so limited that no stratigraphy could be made out. The relations, however, were shown in a locality about forty miles to the west, in a gorge cut by the Hudson river. Between the points where the Indian and the Boreas rivers join the Hudson there are about eight miles of rapids, frequently bounded by cliffs. Here a section is displayed, notably in the cliffs forming the "Blue Ledge" and in the cliffs above "Carter's Riff." It is evident that gneiss, schist and limestone constitute a single conformable series, the gneiss being beneath, the schist forming bands interstratified with both gneiss and limestone. It is further evident that the contact between gneiss and limestone is not a sharp one. There is an alternation of thin beds of gneiss and of limestone, passing upwards into pure limestone.

The evidence from the gorge of the Hudson can certainly be applied to the same rocks when too much crushed to show structural relations. In the Paradox Lake quadrangle both faulting and crushing have been excessive, but it is safe to conclude that here also the gneiss is beneath, the limestone above, with more or less intermingling along the contact.

Sillimanite gneiss. The outcrop of this rock at the mine at Graphite has already been described by Professor Kemp.[1]

Both the foot and the hanging walls of the mine consist of it. The garnet and graphite are the only minerals to be distinguished in the hand specimen. The graphite of the mine is developed in a quartzose layer along which there has been shearing in the direction of the bedding.

Another occurrence of sillimanite gneiss is on Bear Pond mountain, but it differs slightly from that at Graphite. Garnets made

[1] Geology of Washington, Warren and Essex Counties N. Y. State Geol. 17th An. Rept 1899. p.539.

up a large proportion of the rock at Graphite, while on Bear Pond mountain they are entirely absent. Whereas the Graphite occurrence is massive, the Bear Pond mountain variety consists of thin layers interbedded with sandy quartzite. There has been much shearing and crumpling, and the whole series is impregnated with iron oxids. The bedded nature of this sillimanite gneiss is certain.

At Graphite, limestone has been found in a prospect boring, beneath the sillimanite gneiss. At Bear Pond mountain the sillimanite gneiss overlies the hornblende gneiss, no limestone being present. These relations suggest the possibility of an unconformity between the sillimanite gneiss and the limestone series, although the limestone is so patchy in its general distribution as to prevent too confident drawing of conclusions.

The graphitic sandstone occurs in a small area about North pond. It is a gray variety, weathering red, dipping steeply west, and containing abundant flakes of graphite and of mica. On the northeast bay of Rock pond a small mine has been opened. The graphite occurs along a fault line, associated with iron pyrites. Slickensides are abundant in the opening. The country rock is the above described quartzose gneiss, of probably sedimentary origin. The biotite schist, commonly interbedded with the limestone, appears near the mine. The sillimanite gneiss is present on the neighboring mountain. The strike of the graphitic sandstone is n. 5 e., its dip 70 w.

The sandstone is similar to the layer bearing the graphite at the mine of Graphite. The chief difference is that whereas at the Graphite exposure flakes of graphite form the principal constituent of the rock and the only scaly constituent, at North pond mica is also present. The North pond rock is hence less valuable economically, since it not only contains a smaller percentage of graphite, but the process of concentration would be complicated by the presence of two scaly minerals. Both rocks contain much accessory pyrite, and weather yellow or red.

Geologically the two rocks probably represent the same formation, and both are intimately related to the sillimanite gneiss. The silli-

Plate 11

Penfield limestone belt with interbedded schist

manite gneiss represents shale, and the graphitic rock the sandstone of the same series.

Shaly quartzite. Overlying the garnet-sillimanite gneiss of Graphite is a quartzite, impure and feldspathic, in some localities sheared into a schist. It occurs also in the bed of the brook at the extreme southeastern corner of the quadrangle. Several fault lines can be seen along the brook, the most notable one being at the Hague gristmill [*see* pl. 8, fig. 1].

The exposure at the graphite mine in the village of Graphite is separated from an eastern one at the Lakeside mine, Hague, by a hill of syenitic gneiss and by drift in the valley. The uniform strike for both localities is n. 65 e. and the dip of variable amount, toward the southeast. The eastern exposure would hence appear to be the upper one, but the frequency of faults makes its position uncertain. Some layers at the extreme eastern edge of the map are conglomeratic.

Summary of stratigraphic relations. The oldest rock is the hornblende gneiss; conformably above this is limestone; interbedded with both is the biotite schist. Above these, possibly with an unconformity, is the sillimanite gneiss; interbedded with it as a local variation is shaly quartzite; above these, graphitic sandstone.

Intrusives. It has long been recognized that the core of the Adirondacks consisted of a rock of the gabbro family which has been named anorthosite. It has also been long recognized that gabbros of later age than the anorthosite were widespread. Of late years another type of intrusive has been recognized by Dr Smyth on the west and by Prof. Cushing on the north, and has since been found throughout the region, the most common phase of this rock being a syenitic one. All of the above types occur in the Paradox Lake quadrangle. A fourth variety which has not yet been recognized as a distinct type, although phases of it have been described, is also present in large amount in this quadrangle. This will be here called the Pharaoh type from the mountain where it is best exhibited. It presents the general mineralogy of a granite, but appears to be a different rock and older than the granite found in the

northern and western Adirondacks. The anorthosite, syenite and granite are all characterized by sudden and very great variations in the distribution of the ferro-magnesian constituents. These constituents may be gathered together, giving the rock locally the appearance of a gabbro, or they may be wanting altogether, giving in the case of the anorthosite a pure plagioclase rock, in the case of the syenite a plagioclase, orthoclase and microperthite rock, and in the case of the granite an orthoclase, quartz, microperthite rock. The basic varieties are the confusing ones, for with increasing ferro-magnesian constituents the three types approach each other very closely. Later than all three is the typical gabbro. All are plutonic and younger than the sediments.

Granite. Granitic rocks form a considerable area in the southwest, including Pharaoh mountain and several unnamed peaks of some importance. The rock, usually pink in color, is a hornblende granite, but sometimes contains considerable quantities of biotite. It is frequently gneissic, the granite gneiss sometimes being hard to distinguish from the syenite gneiss and the gabbro-gneiss. The igneous gneisses may readily be separated from the sedimentary ones by their massive character and by their uniform appearance over wide areas.

That this granite is later than and intruded into the limestone series is indicated by numerous pegmatite dikes and bosses. In passing from Mount Pharaoh to Mount Treadway one traverses first coarse granite dikes, then pegmatites, and finally to the east of Treadway, quartz veins. This is strongly suggestive of the natural and normal relations which so often occur around intrusives.

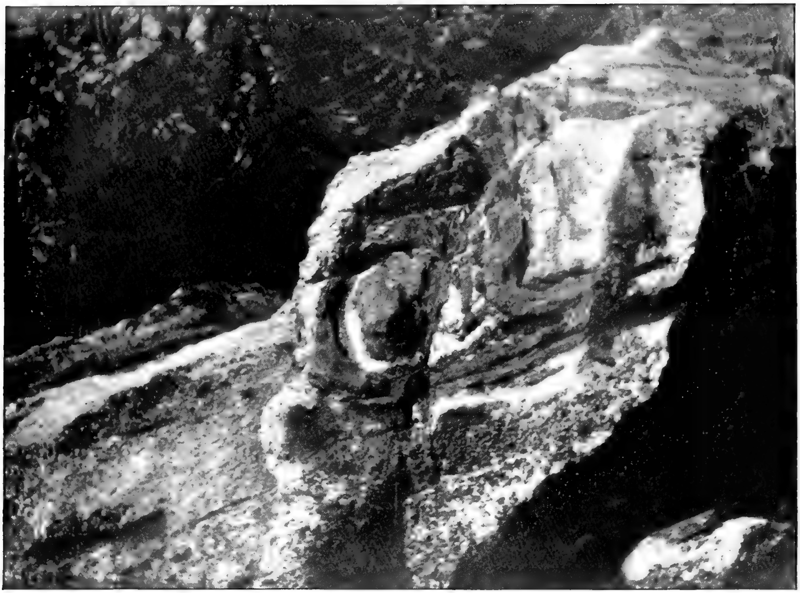
Syenite. Rocks of this type are proving to be one of the commonest of Adirondack intrusives. The type was first described by Dr Smyth, and has since been found in many localities, proving to be an extensive component of the gneissic areas.[1]

The occurrence in the Paradox Lake quadrangle is in all respects similar to those already described.

[1] Smyth, C. H. jr. Geol. Soc. Amer. Bul. 6:271-274; N. Y. State Geol. 17th An. Rept 1899. p.471-486.

Cushing, H. P. Geol. Soc. Amer. Bul. 10:177-192; N. Y. State Geol. 18th An. Rept 1899. p.105-109.

Plate 12



Towner pond. Recrystallization of limestone, accompanying twisting of interbedded schist

The typical appearance of the rock is massive, with a dark green color. It has a tendency to weather far below the surface, and when weathered the color changes to yellow or brown. It is often of gneissic structure, and when this is the case the color often becomes a dark gray.

As shown on the map, the syenite occurs in several isolated areas, the largest being in the northeast. Another smaller area is on the eastern shore of Schroon lake, where syenite and granite grade into each other without perceptible contact.

In the southeastern syenite area, on the mountain 1913 feet high, locally called Trumbull (not the Trumbull of the map) there occurs an interesting exposure of sedimentary gneiss in the midst of syenite. It forms a small eastern spur of the mountain and is too large to be a fragment torn off by the intrusion. It must represent an area of the sediment yet in place, at the top of the intrusion and surrounded by it.

Anorthosite. As shown on the map, there is a large area of anorthosite in the northwestern part of the quadrangle. This area marks the southern and eastern extension of the intrusion which forms the main mass of the highest mountains in the Marcy region. The topography of this section is more rugged, with higher mountains and deeper valleys than the surrounding areas of gneiss, this difference being probably not due to greater hardness in the rock but to two dome-shaped uplifts.

The name "anorthosite" has been often erroneously criticized because of a supposed mistake in the first determination of the feldspar. It was not named from anorthite, but from "anorthose," which was an early French name for all triclinic feldspars as opposed to "orthose," for all monoclinic ones. Hence "anorthosite" means literally "plagioclase rock."

The anorthosite is typically a coarse grained rock of bluish or greenish color containing large irridescent crystals of labradorite. The dark silicates are usually gathered together in bunches, the prevailing rock consisting of feldspar only. About the border of the anorthosite area the rock is gneissic. As already mentioned, the

anorthosite area occupies a central position in the Adirondacks. The area within the Paradox Lake quadrangle comprises a segment of the outer portion of the intrusion, and in it a series of metamorphic changes are evident. These will be described in part 4, on petrography.

The anorthosite forms the highest and most rugged mountains in the quadrangle.

Gabbro. In a few small patches gabbro rocks occur—true gabbro, norite, and hornblende gabbro (meta-gabbro). The most important exposure is on Peaked hill.

The gabbro is typically a medium grained rock, of greenish black color. The dark color serves to separate the rock from the anorthosite and syenite.

Several dikes of the gabbro are found. On the southern shore of Pharaoh lake a gabbro dike cuts gneiss; on Bull Rock mountain (called Old Fort on the map) a gabbro dike cuts the syenite; two dikes southwest of Chilson cut graphitic sandstone; one dike about a mile west of Chilson cuts sedimentary gneiss; on Moose mountain a very basic gabbro dike cuts anorthosite.

The gabbros can in many localities be traced directly into hornblende schists, or amphibolites, and there is no doubt that many dikes of these gabbros exist. But in some localities, as on Ellis mountain in Hague, dikes are exposed which are purely schistose, with no trace of massive facies. It becomes a matter of some difficulty to determine whether such dikes belong to the syenite intrusion, or to the gabbro, or whether they represent a distinct intrusion in themselves. It is upon the age of these dikes that the relative ages of the syenite and granite depends. The granite is frequently cut by dikes of hornblende schist; if these could be proved to belong to the syenite the relative age would be established. In the localities on the south shore of Pharaoh lake and on the mountain west of Goose pond these schists occur, grading directly into massive gabbros. In the last-mentioned locality are a series of dikes of pure schist, precisely like these questionable ones which so frequently cut the Pharaoh gneiss, but fortunately in one a massive facies was found which placed this set with the gabbros. It is

therefore probable that most of the dikes belong with the gabbro. Nevertheless some of the basic portions of the syenite mass present the mineralogy of a gabbro, and if sheared would pass into amphibolites.

Summary of evidence of relative age of igneous rocks

The anorthosite is cut by gabbro at Johnson pond and on Moose mountain; the syenite is cut by dikes of gabbro on Bull Rock mountain (called Old Fort on the map), at Chilson, and at the foot of Cat mountain.

The relation between syenite and anorthosite is doubtful, no contacts between the two having been found. Dikes, possibly of syenite, cut anorthosite on Blue Ridge mountain.

The relation between syenite and granite is also doubtful, the two types often appearing to grade into each other.

The granite is cut by dikes of amphibolite; some of these appear to belong with the gabbro; others are altogether doubtful and may belong in age with the syenite.

Gabbro is thus the youngest in age; anorthosite, syenite and granite are undoubtedly of nearly the same age and derived from the same source since they present gradations towards each other. Anorthosite, syenite, granite, is the most probable order of intrusion.

Pegmatites. The origin of pegmatites has furnished occasion for much discussion in the past. The close relations of pegmatites to igneous rocks and their occurrence as dikes have led many observers to regard them as true intrusives. On the other hand, their coarse structure and frequent association with quartz veins have led others to the reverse view, namely, that solution was too prominent in their production to admit of an igneous origin; that they are essentially veins, and that they are genetically related to igneous rocks, with more or less of pneumatolytic action at their time of consolidation.

In the northeastern corner of the quadrangle, in the neighborhood of Towner pond, there is limestone in close proximity to intrusive syenite and granite. Contact effects are to be seen in the presence of enormous pegmatites. Roe's spar bed is a famous locality for

minerals,[1] and is a huge pegmatite which has been opened for the economic value of the orthoclase in the manufacture of porcelain. Crystals of biotite, orthoclase and quartz, sometimes over a foot in length, occur at this quarry. Three small diabase dikes cut it, along which are developed tourmaline and titanite. There are several good sized hills consisting of pegmatite in this locality, with smaller pegmatites cutting sedimentary gneiss.

This famous pegmatite can be followed towards the granite intrusion, with increasing biotite as the granite is approached. When followed away from the granite the pegmatite becomes more acid and contains much graphic granite. Small dikes of pegmatite border the mass around the spar bed, these dikes being more acid than the larger ones. Beyond the dikes are veins of rose quartz.

Many pegmatites border the granite of Mount Pharaoh. In this case small dikes only were found. Those near Mount Pharaoh presented the general mineralogy of a granitite, usually with accessory tourmaline or titanite; the more remote ones contained fewer dark silicates.

Pegmatites also occur about the edge of the anorthosite area. These pegmatites contain the same bisilicates as the anorthosite, with quartz, orthoclase and magnetite also.

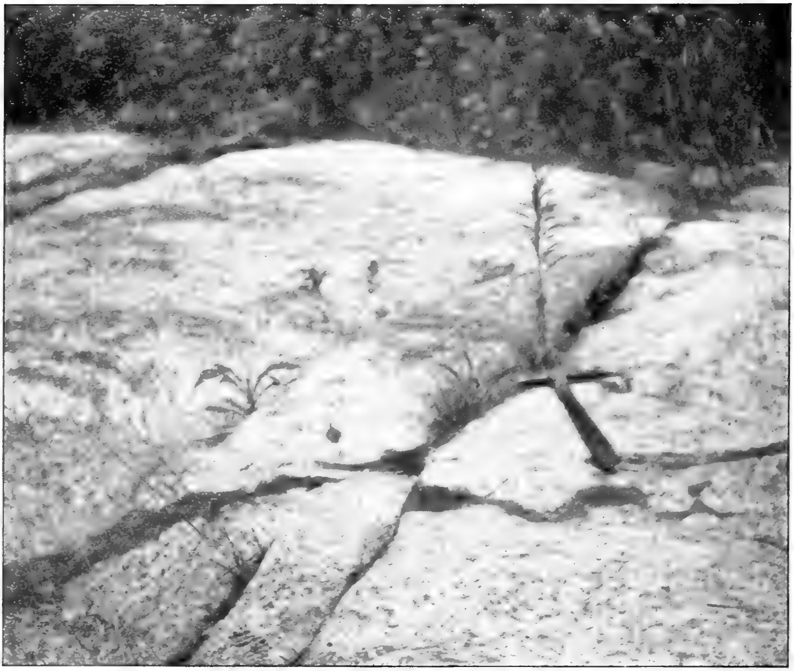
There seems no doubt that these pegmatites belong to the closing stages of the intrusions; and that they are of igneous origin, but were produced with the aid of more water than their associated plutonics.

On the hills about Crane pond pegmatites are particularly abundant near the limestone contacts, while quartz veins predominate in the quartzose gneiss area. There are complete gradations between the two, though any connection with plutonic sources is here cut off by faults. Professor Van Hise has pointed out[2] that the true explanation of pegmatization includes igneous injection, aqueo-igneous

[1] Roe's spar bed has been referred to in the following papers: E. H. Williams, Am. Jour. Sc. 1881, on tourmaline; J. F. Kemp, Am. Jour. Sc. 1888, on minerals near Port Henry; J. F. Kemp on Geology of Crown Point, N. Y. N. Y. State Geol. An. Rept for 1893; J. F. Kemp, U. S. Geol. Survey Bul. 107, on Trap Dikes of Lake Champlain.

[2] C. R. Van Hise. Principles of Precambrian Geology. U. S. G. S. 16th An. Rept pt 1. p.684-687.

Plate 13



Faulted dikes, Pharaoh lake

action, and water cementation; that there are all gradations between the three processes, and that under conditions of high temperature and great pressure, water and magma are miscible in all proportions. It would therefore follow that as a center of intrusion was left, the more volatile constituents of the intrusion would be deposited radially and at the same time percolating superheated ground water, containing in solution various constituents from the wall rock, would become mingled with the plutonic material. There would therefore be a gradation between injection processes and cementation.

These old gneisses seem sometimes to have undergone further cementation with no connection with intrusions. Quartz lenses are frequent in the quartzose gneiss, and so is secondary quartz in microscopic quantities. These occurrences belong to the process of cementation of the rock by infiltration of silica in solution. This cementation may have been a continuous process from the time of the first intrusion, but its greatest development must have been subsequent to the main intrusion, for the reason that the intrusions were all too deep seated to be in the zone where percolating water could have had much, if any, effect.

In résumé it may be stated that the plutonics were intruded at great depths, some pegmatites being contemporaneously developed at their periphery. The gradual migration to the surface, through the removal by erosion of the overlying burden, gave increasing opportunity for the action of percolating ground water, and the exact line at which the boundary is to be drawn between dike and vein, or between vein and secondary crevice filling or enlargement of original grains, can not be sharply established.

Dikes. Trap dikes have been noted in several localities. The dikes on Pharaoh lake have already been described in the report previously referred to. They are of diabase, and form an anastomosing network running across the strike of the gneiss. These dikes cut pegmatites. They have been more readily weathered than the surrounding gneiss [*see* pl. 10].

There is another diabase dike on the north side of Treadway mountain. It outcrops on the face of a small cliff.

At Roe's spar bed, one mile south of Towner pond, three diabase dikes cut the huge pegmatite exposure. One occurs near Fleming pond, one mile south of Hammondville; another in the gneiss a mile northwest of Penfield pond.

Acid dikes of the type known as Bostonite were found in two localities: one at Heart pond, the other north of Worcester pond. These dikes are bright red and are very small.

Palaeozoic formations. *Potsdam sandstone.* As shown on the map, the Potsdam occurs in three localities. Of these the Chilson area is the most important. There are three good outcrops in this area. On the hill near the gabbro are ledges of yellowish quartzite, and not far away in the fields are several small outcrops of conglomerate. The conglomerate and reddish sandstone represent the basal Potsdam. Farther east in the brook is an exposure showing the contact with gneiss. This also is the reddish lower facies. To the south on the road to Putnam pond is an outcrop of a gray color, which represents the upper facies and is slightly calcareous, showing a gradation towards the Calciferous.

These exposures all rest unconformably upon the quartzose gneiss, and the conglomerate contains pebbles of the same gneiss.

The Crown Point area of Potsdam sandstone is a small remnant of the reddish yellow type. It has the usual strike of n. 10 e. and dip of 10 n. w. A pretty little postglacial canyon, with some cascades, is to be seen where the north branch of Putnam creek crosses this Potsdam area. Many loose boulders of Potsdam sandstone and of Calciferous, Chazy and Trenton are scattered about the fields near this locality. These rocks are not glaciated but indicate the former presence of these formations in the valleys.

The exposure on Trout brook shows interesting cutting of the stream channel laterally down the dip, with resulting cliffs on the down-dip side. The rock is the reddish variety, with a strike of n. 20 e. and a dip of 15 n. w.

Trenton limestone. In a cut of the abandoned railroad, about a mile west of Ironville, are a series of small exposures of dark gray limestone, containing typical Trenton fossils. A steep and very variable dip, with some variation in strike, points to the possibility

Plate 14

Faulted dikes, Schroon lake

that these rocks were not in place, but since they showed no sign of glaciation they were regarded as probably representing an erosion remnant. An interesting sheared zone was observed in one of these exposures. A strip about an inch wide had been slickensided and completely recrystallized, the many fossils of the side walls completely disappearing. The sheared zone consisted of pure calcite, polysynthetically twinned. The following fossils were identified from this locality:

Trinucleus concentricus

Calymmene senaria

Ceraurus pleurexanthemus (*Green*)

Bathyurus (?——)

Protowarthia cancellata

Dalmanella testudinaria

Glossina trentonensis (Lingula attenuata *Conrad,* L. rectilateralis *Emmons*)

Platystrophia biforata

Faults. Dislocations of varying magnitude are very widespread. As no stratigraphy can be made out the amount of displacement can not be ascertained, nor is the age always capable of determination. A prominent fault cliff extending some five miles in a n. 15 e. direction from Knob mountain has already been noted by Professor Kemp. The breccia of this fault is displayed in a cut of the abandoned railroad. As fine a scarp extends in the same general direction southwards from Bear mountain. There is a general parallelism among the various sets of faults in their general directions, but they often curve through a considerable angle. These northeast-southwest scarps are much the freshest and are probably the latest.

The northwest-bearing fault along the base of Treadway mountain is interesting in that its breccia showed infiltrations of iron oxids bearing pyrite and scales of graphite. The graphite was here undoubtedly formed by a secondary deposition, but was probably derived from the limestone or sandstone. Another set of faults strikes eastwest.

The numerous faults are outlined on the map. Their presence is usually indicated by a cliff, but some of the older ones have weathered so as to be recognizable only from a crushed strip. Many of these may have been overlooked in consequence of the dense vegetation and lack of paths or of outlook.

Shear zones. About three miles west of Graphite are three parallel gorges with an east-west direction, the largest of which is locally known as the "Ice gorge." These three gorges are established along three shear-zones. The nearly perpendicular cliffs of the ice gorge are about 500 feet high, while those of the smaller gorges are about 200. The country rock is a porphyritic gneiss, with large orthoclase phenocrysts in a quartzose ground mass, and containing much biotite. The rock from the sheared zones presents a granulation of constituents with an infiltration of iron oxids.

Small faults and shear zones are of almost universal occurrence in this region and traverse all types of rock.

Foliation. This structure is common to all the Precambric rocks, and the general direction of strike is similar. A direction of n. 40 e. is the prevailing one, with low southeast dips. Since the direction of foliation is common to all the rocks, it must have a common origin; since no relation is shown between direction of foliation and any of the intrusives, the structure can not be due to igneous agencies. It appears to result from a thrust from the southeast, while the rocks were still deeply buried.

A similar and later thrust when they were nearer the surface appears to be the cause of the faults.

Joints. The Precambric rocks are extensively jointed, the joint planes running in all directions. The joints are usually vertical and as a rule only two sets, nearly at right angles to each other, are present. Occasionally a third, highly inclined joint is present. Their directions are too inconstant to be reduced to any system.

PART 4

Petrography

It was found difficult to distinguish macroscopically among the basic phases of the three intrusive types—anorthosite, syenite and granite—since with increasing ferro-magnesian minerals they ap-

Plate 15

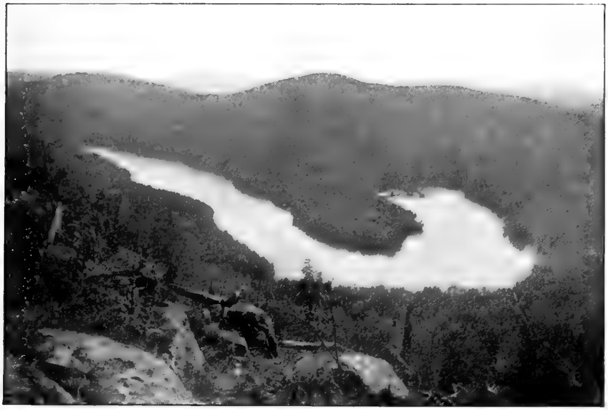


Fig. 1 Gooseneck pond; a faulted rock basin

Fig. 2 Gooseneck pond; a faulted rock basin

proach each other. They also approach very closely to the fourth intrusive type, namely, the gabbro. It was possible, however, to trace these basic developments into masses typical of the classes to which they belonged, and with microscopic work the distinctions became clearer. On the map the areas were colored according to their genetic relationship and they were named according to the most prominent type of a single formation. The map is therefore not lithologically accurate, since rocks that could properly be named *gabbro*, or *diorite*, are included within both syenitic and granitic areas. Only those were mapped as gabbro which could be recognized as distinct in age from the other three intrusions.

The relationships are further complicated by the intense metamorphism, all four types frequently being gneissic. The granitic gneiss approaches the syenitic gneiss on the one hand, the sedimentary hornblende gneiss on the other, while anorthosite gneiss often resembles syenite gneiss or gabbro gneiss. Hence the only possibility of unraveling their relationships is by studying them over wide areas.

The difficulty is further increased in that preglacial valleys were usually established along the contacts, these contacts now being masked by drift and swamp.

The boundaries on the map are therefore subject to some doubt; in some cases several miles of swamp occupy the contact, in others gneisses appear to belong with almost equal accuracy to either of two types. But although the boundaries may be a matter of dispute, it is confidently believed that the high mountains in the northwest consist of anorthosite; that these are bordered on the east and south by a sedimentary belt; that Pharaoh mountain marks the central part of a granite intrusion, and that the mountains of the southwest consist of the syenite.

Petrography of sedimentary rocks

Hornblende gneiss. As before stated, this rock is extremely variable in mineral composition. Streaks of biotite schist are interbedded with it; granite, syenite, anorthosite, pegmatites and trap cut it. The country rock itself is variable in composition, and has

been highly metamorphosed and recrystallized. Thin sections of this rock from Mount Treadway exhibit quartz, feldspar, hornblende, biotite, piedmontite, magnetite and ilmenite. There is every evidence of intense metamorphism. The quartz is strained, with undulatory extinction. The feldspar is mainly microcline, with subordinate plagioclase, and both feldspars show strain effects. Anorthoclase is often present. The plagioclase is usually oligoclase, but both albite and labradorite are sometimes found. Large pink garnets are sometimes present. The biotite is a very black variety, pleochroic from black to pale brown, and often exhibiting pleochroic halos. The piedmontite is small in amount, but is present in nearly all the slides examined of this type of rock.

Considerable variation in the amount of metamorphism is to be seen in this series, and some variation in the relative quantities of constituents. On Third Brother the maximum of strain is reached; some of the feldspars are bent through a large angle, and all feldspar and quartz show undulatory extinction. Microcline is the predominating feldspar. Piedmontite is abundant. Several brecciated zones were found on the sides of the mountain and near its top; at first sight they resembled serpentine dikes, but closer study showed them to be small shear zones. These fault breccias showed prevailing secondary minerals, quartz, epidote, chlorite and related minerals. Faint traces of hornblende were made out, nearly altered to chlorite with finely divided epidote and calcite. The plagioclase was completely altered to kaolin and saussurite. Some magnetite is present. Precisely similar rock occurs northwest of Penfield pond, and on the hill northeast of Paradox lake. The commonest type is somewhat less strained, with hornblende and biotite in about equal amounts, and with microcline, plagioclase and orthoclase in decreasing order of abundance. Quartz is always the most common mineral.

On the mountain erroneously called Trumbull on the map (the local name is Ellis) is found the least altered variety of this rock. No microcline was present, but a larger proportion of orthoclase altering to kaolin and zeolites. The quartz was less strained; the biotites showed no halos; no piedmontite was found.

The quartz usually constitutes about 40% of the rock; feldspar over 50%; the remaining dark silicates being thus small in quantity. Unfortunately the rock was invariably too greatly weathered for an analysis to be accurate, but it is confidently believed that if such an analysis could be made the silica content would be high enough to place the rock without doubt among the sediments.

The biotite schist which forms bands in this gneiss and in the limestone is found to contain large quantities of quartz. Quartz forms from 20% to 30% of the rock and biotite is present in about the same amount. The remainder of the rock is made up of feldspars (microcline, albite, labradorite and oligoclase all being found, usually one variety predominating and one other being less in amount), garnet, zircon, apatite, and magnetite, in varying proportions.

The probability concerning this gneiss is that it represents the base of the Grenville series, which has suffered from the metamorphism common to the region as a whole, and which has experienced in addition an excessive amount of recrystallization and squeezing from being nearest to the intrusives.

Sillimanite gneiss. Thin sections of the rock at Graphite show large garnets embedded in a mass of fibrous sillimanite. The sillimanite crystals show a roughly parallel arrangement. A little quartz is present and accessory zircon, pyrite and graphite. The foot and hanging wall are similar, except that the foot wall contains microperthite in addition to the minerals found in the hanging wall.

The sillimanite gneiss from Bear Pond mountain contains similar shreds of sillimanite. Biotite is present in large quantities, the biotite being younger than the sillimanite. In the prevailing type shreds of biotite and of sillimanite are arranged in parallel groups, the terminal faces of both being lacking. Occasionally a sillimanite crystal is found cutting across the biotite at right angles to its long axis, and in such cases it is the sillimanite that has the perfect boundary. Accessory pyrite and rutile are sometimes present.

Petrography of the igneous rocks

Of the four types of igneous crystalline rocks found on the Paradox Lake quadrangle—granite, syenite, anorthosite, and gabbro—

only two, the anorthosite and gabbro, were recognized as intrusives in the preliminary report on the region. The granite and syenite together constituted a "doubtful" area which was, for convenience, called "Series 1," the presumption being that they were older than the limestone and possibly to be correlated with the Ottawa gneiss of Canada.

Granite. The granite of the Paradox Lake quadrangle is usually gneissic.

It is believed to be igneous because of its constant composition over wide areas; it is regarded as intrusive into and younger than the sedimentary hornblende gneiss because of the small dikes and pegmatites which appear to radiate from the granite, cutting the sedimentary gneiss.

In no case could a true intrusive contact be found. In most localities where the two gneisses come together, or where the massive granite gneiss is in contact with the limestone, faulting is found to be the cause. Where there is no fault in evidence, the contact is obscured by swamps.

In mineralogy this granite-gneiss is very constant. It contains hornblende, orthoclase, plagioclase and quartz, with occasional accessory biotite, muscovite, magnetite, pyroxene, apatite and zircon. Some slides of this rock present the normal appearance of a hornblende granite, but usually the minerals are drawn out into gneissic bands, the orthoclase changed to microcline; the quartz showing undulatory extinction; the hornblende bent and twisted but unaltered optically. Tiny shear zones are common, filled with secondary quartz, chlorite or zeolites. Secondary garnets are occasionally present, but are not so common as in the more basic rocks. Intergrowths of quartz and orthoclase (micro-perthite) are common.

Another variety is porphyritic, with phenocrysts of orthoclase.

Still another variety is that which contains the Hammondville ores. This type is conspicuous in the absence of ferro-magnesian minerals, consisting mainly of quartz, microperthite and plagioclase. A scattering of magnetite grains with very rare hornblende are present as slight accessories. The hornblende is usually brown. Occasionally the green variety is found.

Plate 16

Mt Pharaoh, from Crane pond. Granite gneiss

The quartz sometimes occurs in grains, but more often, especially in the crushed varieties, in lenses. Evidently in some cases the quartz has been enriched secondarily.

The structure is frequently cataclastic, the constituents appearing to be in grains resulting from the crushing of larger crystals. The rocks possessing this structure pass by insensible gradations into true granites, and there can be little doubt that the gneisses exhibiting this structure are crushed portions of the granite.

The rock found in Pharaoh mountain is the most wide-spread type. It presents a general pink appearance in the hand specimen, and under the microscope proves to be a hornblende-granite-gneiss.

The Pharaoh type contains about 50% of feldspar. Predominating orthoclase, with accessory albite or oligoclase, is probably the normal composition, but these have usually been replaced by microcline and microperthite. Primary quartz constitutes about 30% of the rock, although the actual quartz content is almost always increased by the presence of secondary lenses and veinlets. The remaining 20% is made up of hornblende and the accessory minerals.

Syenite. As already mentioned, the syenite of the Paradox region belongs to the syenite type of Cushing and of Smyth. The preliminary reports on the Paradox region were published before this type was recognized, and it was included within the "doubtful" area.

In thin section a cataclastic structure is commonly found. There is much variation in mineral contents, there being a complete gradation from an augite syenite containing microperthite to a type closely resembling the granite and consisting essentially of hornblende, microperthite, subordinate augite, quartz and a little biotite. There is constant likeness between this type and the granite of Mount Pharaoh in the presence of intergrowths of several different minerals. Microperthite (consisting of intergrowths of orthoclase and albite) is a normal component, and less frequently there occurs (in the syenite only) an intergrowth of green augite with bronzite or hypersthene. Quartz is usually present in the syenite, and its often elongated lens-like form suggests that it is secondary. Some primary quartz is present also. The pyroxene is a bright emerald green variety.

The syenite from the southeastern area contains as essential minerals microperthite, a deep green nonpleochroic augite, small amounts of hornblende and of quartz, with accessory apatite, magnetite, zircon and garnet, the last named perhaps secondary.

The syenite from the area on the eastern shore of Schroon lake contains relatively more hornblende and more quartz.

In the Crown Point area labradorite is present in addition to microperthite.

Within the anorthosite area of the Blue Ridge, about a mile from the boundary of the syenite, are three dikes which cut the anorthosite. These dikes contain green augite, labradorite, and very abundant garnet. They appear to belong with the syenite intrusion, and if so, would indicate that the syenite is younger than the anorthosite.

Anorthosite. Anorthosite is a coarse grained rock of the gabbro family, presenting the extreme of the series rich in feldspar. Some occurrences consist of pure plagioclase.

In its massive phases the rock is quite fresh. The plagioclase is twinned according to both pericline and albite laws. It is always labradorite. Hypersthene, pleochroic from pink to green, and a pale green, normal augite are the only other minerals which occur in appreciable quantities. The structure is irregular, the bisilicates being grouped together and not evenly distributed through the rock. Associated with the grouping of constituents is a variation in size of grain. When crushed, the dark patches are pulled out into lenticles, or into gneissoid banding. Similar sudden variations in texture have been noted by Professor G. H. Williams, in the Baltimore gabbros.[1]

Hornblende, biotite and orthoclase may be present in small quantities, with accessory or secondary magnetite, titanite, ilmenite, apatite, chlorite, epidote, garnet, zircon and spinel.

An extensive series of metamorphic effects can be seen. In the northwestern portion of the quadrangle the rock is uniformly massive, except when brecciated by faulting. The labradorite crystals

[1] G. H. Williams. "The Gabbros and Associated Hornblende Rocks Occurring in the Neighborhood of Baltimore, Maryland." U. S. G. S. Bul. 28.

show their characteristic irridescence and are an inch or more in length. Farther south and east, along a zone beginning a few miles from the border of the intrusion, the rock is granulated and a cataclastic structure is seen in thin section. If present, the bisilicates are drawn out into irregular bands. If slightly more crushed the rock becomes a gneiss, and as the granulated labradorite is white, it becomes a matter of some difficulty to distinguish in hand specimens between gneissic anorthosite and the sedimentary gneiss. It was this banding which led Emmons to claim a sedimentary origin for the rock. The extreme of metamorphism is seen in a complete mashing and the development of new minerals. On the hill northwest of Paradox lake is a variety which in the hand specimen is an even white color, with no constituent minerals distinguishable, and with large secondary garnets embedded in the white mass. In thin section this white rock is found to consist of broken pieces of plagioclase, and in general the whiter the rock the more complete the granulation. The completely granulated rock resembles a massive limestone. If ferro-magnesian minerals are present they may be drawn out into gneissic bands with a cataclastic structure. Garnet, secondary after pyroxene, often occurs. These intensely granulated anorthosites frequently contain titaniferous iron ore. Prof. Frank D. Adams[1] has suggested that these ore bodies may be due to a gathering together, from crushing, of minute inclusions previously contained in the feldspar. The area in Canada which he describes is remarkably similar to the one under consideration, but the Adirondack area does not contain such an extensive amount of black dust in its labradorite. Titaniferous magnetite occurs in occasional crystals in the massive anorthosite, and its formation appears to be that of a local gathering together of constituents analogous to that of the grouping of the bisilicates. The dark silicates are more abundant in the peripheral portion of the intrusion.

The irregularities in size of grain and in distribution of constituents must be due to processes taking place during consolidation. Whether the processes are chemical in their nature or physical, or

[1] F. D. Adams. Geol. Survey of Canada; Rept J. 1895. v.8.

whether varying specific gravity of the minerals is a factor in their localization is yet to be demonstrated. The granulation of the massive rock and the gneissic banding are undoubtedly secondary effects, having taken place after the consolidation of the rock as a result of pressure.

Garnet is the only undoubtedly secondary mineral present except those which are subsequently caused by a local shear. The occurrence of such intense granulation without a corresponding change in mineralogy (augite to hornblende or uralite, feldspar to saussurite and albite, etc.) is unusual. Prof. Frank D. Adams, in the report already cited, suggests that movement must have taken place while the rock was deeply buried and at a high temperature. The deep burying accounts for the absence of shearing effects; the high temperature for the lack of secondary hornblende, which needs low temperature for its production. The Adirondack occurrence is precisely similar to the Canadian one here described.

Gabbro. The gabbro proper is a basic variety, consisting of labradorite, green monoclinic augite, titanite, sometimes hypersthene and occasionally olivine. It usually presents an ophitic texture, with broad laths of feldspar which have the ferro-magnesian constituents between them. With increasing hypersthene the gabbros pass into norites; with increasing ilmenite and titaniferous magnetite the gabbro passes into the titaniferous iron ores.

The anorthosite and gabbro illustrate the familiar truth that basic rocks are more liable to vary than acid ones. The gabbro family appears to be particularly variable, as is evident from a comparison of the mineralogy of the various types. The gradation from a pure labradorite rock on the one hand to a titaniferous iron ore on the other is a much greater change mineralogically and chemically than is ever known in so small an area among granitic rocks.

The gabbro area near Johnson pond presents a series of gradations from a dark garnetiferous gabbro to a labradorite rich variety, which is practically a pyroxenic anorthosite. In the northern part of this area the more typical gabbro occurs, and its contact with the anorthosite is distinct and suggestive of an intrusion of the gabbro into the anorthosite. In the southern part, however, on Peaked hill,

there is considerable confusion, gabbroic bands alternating with anorthosite in an astonishing manner. The southern and eastern boundary of the area was difficult to determine because of this alternation and gradation of types. In the extreme eastern portion of the area mapped as gabbro there is a rock which seems to represent crushed gabbro. It consists of garnet, of almost microscopic size, which gives the rock in the hand specimen the appearance of a granular aggregate of little garnets. The same rock is found in a series of dikes on top of the mountain 1742 feet high, slightly north of east of Peaked hill.

In thin section the garnet rock is found to be a true gabbro, containing green pyroxene, labradorite, diallage, titaniferous magnetite and garnet. These small dikes differ from the commoner bosses in being of finer grain; in having relatively greater abundance of garnets, and in the presence of diallage.

The occurrence of the small garnetiferous dikes in the anorthosite, and also along the contacts of gabbro and anorthosite, suggests their peculiar structure as due to contact effects. They are certainly a part of the gabbro intrusion, and their occurrence indicates that the gabbro is later than the anorthosite.

The gabbros are usually crushed, and then develop gneisses which can not be distinguished from the gneissic development of the gabbro phase of the anorthosite, nor from the gabbroic part of the syenite, nor from some areas found among the granites.

The gabbros are frequently granulated and show gradations similar to those seen in the anorthosite. There appears also to have been recrystallization in the gabbros. The plagioclase contains many fine black inclusions which may be either pyroxene or titaniferous magnetite, or both. They are apparently inclusions, not alteration products. Similar inclusions have been described by many writers on gabbros.[1] Reaction rims are common.

[1] G. H. Williams. U. S. G. S. Bul. 28.

F. D. Adams. Uber das Norian oder Ober-Laurentian von Canada. Neues Jahrbuch. Band 8, p.425.

A. C. Lawson. Anorthosites of the Minn. Coast of Lake Superior. Minn. Geol. Survey Bul. 8. 1893. p.8.

J. F. Kemp. Gabbros on the Western Shore of Lake Champlain. Bul. Geol. Soc. Am. 5:213-24.

Summary and conclusions

The investigation of the gneissic area resulted in showing the possibility of splitting up the "doubtful gneiss" of earlier reports into three types: (1) Syenite, which is igneous in origin and is in all respects similar to the syenite previously described in other Adirondack localities. (2) Granite. (3) Quartzose gneiss of sedimentary origin, which may be the rock that has sometimes been termed "gneiss of the limestone series." The syenite is without doubt a plutonic igneous rock, and although gneissic phases are common, completely massive ones predominate. The granite is more completely gneissic, and for that reason there is less certainty in determining it. Both syenite and granite are alike in presenting variations in the percentages of ferro-magnesian constituents. The third type of gneiss is the most highly metamorphosed. It contains so many intrusions of small size both of syenite and of granite that it was found impossible to mark them off in mapping. It was further altered by secondary infiltration of quartz, both in the form of large veins and of disseminations of microscopic size.

The presence of these small intrusions affords evidence that the granite and syenite are younger than the quartzose gneiss; and the character of the rock, its macroscopic and its microscopic appearance, and the topography of its mountains point toward a sedimentary origin. Its frequent association with the limestone (occurring sometimes in thin layers folded with the limestone, sometimes in hills while the limestone occupies the intervening valleys) points toward the conclusion that this quartzose gneiss is a member of the limestone series. Since this gneiss underlies the limestone, and also underlies the other gneisses which are of sedimentary origin, it is thought to represent the base of the Grenville series. In its basal position is to be found the explanation of the great number of intrusive masses which render this rock so difficult of interpretation in the field. Being at the bottom of the sediments, it formed the portion most subject to alteration from the intrusions, and it now contains within its mass remnants of what were apophyses from the top of the intrusions.

Of the relative ages of the intrusives, the only evidence is that of somewhat doubtful dikes. Some of the dikes are undoubtedly gabbro and cut all the other Precambric intrusives; others may be syenites and cut anorthosite, and possibly granite. Granted that these dikes cutting granite are not syenite, the field relations point strongly to the younger age of the granite. Both in this region and elsewhere[1] the syenite is bordered by granite, the granite being much more gneissic than the syenite. Gradations between the two are common. It seems most reasonable to regard the granite as a border development of the syenite, derived from the same magma, and very slightly younger in age.

Regarded from this point of view the Adirondacks form a well marked petrographic province, presenting rocks with very great variations in composition, grading from ultrabasic to acid, but all to be regarded as derived from one magma by differentiation.

The great complexity of Adirondack structure results from the fact that these intrusives, together with the sediments of the Grenville series, into which they were intruded, have all been crushed so as to present similar planes of foliation, and at a later time have been extensively faulted.

PART 5

Economic geology

Graphite. Graphite and iron ores are the only products of economic importance. The graphite is mined at two localities, and occurs in many places on the quadrangle. The demand for graphite in fine scales is limited, hence the industry has not developed to the full extent of the workable material. The mines at the town of Graphite have already been described by Professor Kemp;[2] the graphite there occurs as drawn-out flakes among quartz grains in a layer bounded above and below by the garnet-sillimanite gneiss. There has been faulting, and the graphite has suffered from a shear along the bedding. At Rock pond, where a small mine has recently

[1] H. P. Cushing. "Recent Geologic Work in Franklin and St. Lawrence Counties." N. Y. State Geol. 20th An. Rept 1902. p. r23-r82.

[2] N. Y. State Geol. 17th An. Rept 1899. p. 539.

been opened, it also occurs along a line of movement in a gneiss which is probably of sedimentary origin but is not graphitic. In various other localities prospect holes have been opened, and whereever successful there is evidence of shearing. The sandstones and limestones which are charged with small amounts of graphite are not far from all of these openings, but the wall rock is apparently never a markedly graphitic one. Less than half a mile east of the Rock pond locality the graphitic sandstone occurs on North pond; the drill cores at Graphite went through graphitic limestone. It therefore appears as though the graphite deposits were a result of impregnation along a line of weakness by some products, possibly volatile hydrocarbons, originating from the distillation of originally fossiliferous sediments.

Thin sections of the shear zone at the western front of the cliffs of Treadway mountain reveal flakes of graphite. The bounding rock is the quartzose gneiss of probable sedimentary origin, and the graphite flakes appear secondary and are evidently related to an infiltration of iron-charged solutions. Pyrite invariably occurs associated with the graphite, and sometimes limonite and magnetite as well. Any theory of the origin of graphite must explain its association with these iron compounds.

Dr Ernst Weinschenk has recently published a series of papers entitled " Zur Kenntniss der Graphitlagerstätten," in which he takes up occurrences of graphite in various European localities. He finds that graphite may occur either as a result of contact metamorphism from a large intrusion of any kind into a calcareous formation, or from injection in gaseous condition along planes of weakness in a disturbed area. He finds that graphite is never to be regarded as the final step in the process of coal formation, and that at least in the Alps and in Ceylon the graphite is not due to regional or to dynamic metamorphism.

The Adirondack graphite is plainly of two kinds: that present as an accessory constituent of the limestone and quartzite, and that occurring in a secondary position along fault lines. The latter occurrence appears analogous to that described by Weinschenk as

Plate 17

A graphite nodule in limestone. Ironville road

intrusive along planes of weakness, and can only be explained as an injection of carbonaceous and ferruginous materials in a fluid or gaseous condition. A reducing action of iron compounds on hydrocarbons might result in the formation of the graphite and pyrite which we constantly find associated.

But the widespread dissemination of graphite scales in sedimentary limestone and quartzite can best be explained on the organic hypothesis. There seems no possibility of any origin but that of a metamorphic product from some original constituent of the rock, and regional metamorphism is the only process by which it can reasonably be supposed to have been formed. It seems most probable that the original limestone and sandstone were heavily charged with organic material which in the Prepotsdam period of metamorphism was completely reduced and in some part volatilized. The organic material thus reduced remains in its original position as graphite, while the volatilized portions spread along every available plane of weakness and form the deposits of economic importance.

Titaniferous magnetite. Titaniferous iron ores appear on Moose mountain. The occurrence of these ore bodies is evidently to be explained in the same way as the aggregation of minerals in the anorthosites. The titaniferous ores always occur in the anorthosite, or gabbro, and represent the extreme development in the direction of producing an aggregation of iron minerals. The process is entirely analogous to that of the production of anorthosite from gabbro by increase in feldspar, or of pyroxenite from gabbro by the decrease in augite. There is no evidence of intrusion, nor of vein formation in the occurrence of these ores, nor have they any relation to faults or crushed zones. The titaniferous iron ores of the Adirondacks have been fully treated by Professor Kemp.[1]

Nontitaniferous magnetites. Reference has already been made in Professor Kemp's preliminary report[2] to the magnetite deposits of Hammondville and to the Schofield ore body. Both deposits occur in the granite of a type containing almost no ferro-magnesian

[1] U. S. G. S. 19th An. Rept pt 3. Economic Geology. p.379-422.

[2] Geology of Essex County. N. Y. State Geologist An. Rept for 1893 and 1895.

minerals. Both localities are very extensively faulted; the face of Skiff mountain shows a fault cliff, and at Hammondville fault breccias are of frequent occurrence.

Magnetite was found by the writer in the Desolate brook valley, southwest of Pharaoh mountain. It had been tapped by a mine, apparently long abandoned. The foot and hanging walls were of the same type of granite as those of the former localities.

These deposits are in striking contrast to the titaniferous ore bodies, the magnetites showing no intimate relation to the wall rock. The conclusion seems inevitable that they are foreign to the granite, and produced in connection with one of the later intrusions, probably secondarily enriched by percolating water. Similar ores near Port Henry[3] have been described by Professor Kemp. There the ores are associated with an igneous intrusion of gabbro; they are always within an acid gneiss, but their proximity to the gabbro renders their origin as contact occurrences the most reasonable view.

The Hammondville and Schofield ore bodies are cut off by faults from all neighboring intrusions, but their most probable relationship seems to be with intrusive action.

The alternative hypotheses would be either to regard the magnetite as a metamorphosed sedimentary bed and the Hammondville gneiss as a sediment, which is improbable in view of its similarity to the Pharaoh granite; or else to consider it a magmatic segregation from the granite, which seems improbable in so acidic a rock, notably poor in iron.

[1] J. F. Kemp. Geology of the Magnetites near Port Henry N. Y. and especially those of Mineville. Trans. Am. Inst. Min. Eng. 1897.

INDEX

The superior figures tell the exact place on the page in ninths; e. g. 500^3 means page 500, beginning in the third ninth of the page, i. e. about one third of the way down.

Adams, Frank D., cited, 499^6, 500^3, 501^8.

Adirondacks, topography and geology, 461^7–63^2; faulted region, 462^2; trellised drainage, 462^4; recent geologic work, 463^2.

Albite, 494^3, 495^3, 497^4.

Anorthosite, 483^7, 485^5–86^2, 493^9, 495^9, 500^9, 503^2; description, 498^4–500^5.

Apatite, 495^4, 496^6, 498^1, 498^8.

Augite, 497^7, 497^8, 498^1, 498^3, 498^6, 500^5.

Biotite, 494^1, 494^3, 494^7, 494^9, 495^3, 495^7, 496^6, 497^7, 498^8.

Biotite schist, 493^9, 495^2.

Brigham, cited, 462^4.

Bronzite, 497^8.

Calciferous outlier, 467^9.

Calcite, 494^7.

Cambric drainage lines, 465^5–67^9.

Chilson lake, valleys, 466^8.

Chlorite, 494^6, 494^7, 496^7, 498^8.

Cirques, 476^1.

Crown Point, 470^9–72^5.

Cushing, H. P., work on the geology of the Adirondacks, 463^4; cited, 469^4, 484^9, 503^9; mentioned, 483^7.

Desolate brook, 477^3.

Diallage, 501^3.

Dikes, 489^8–90^2, 503^1.

Drainage modifications, 469^7–78^4.

Economic geology, 503^6–6^7.

Emmons, E., geologic work on the Adirondacks, 463^3; cited, 472^6, 499^3.

Epidote, 494^6, 494^7, 498^8.

Faults, 491^5–92^2.

Feldspar, 494^1, 494^2, 494^5, 495^1, 495^3, 497^4, 498^4, 500^6.

Foliation, 492^5.

Gabbro, 486^3–87^2, 495^9, 498^7, 503^1; description, 500^5–1^9.

Garnets, 494^3, 495^4, 496^7, 498^2, 498^4, 498^8, 499^4, 499^5, 500^2, 501^2, 501^4.

Glacial deposits, 469^7–78^4.

Glaciology of the Paradox Lake quadrangle, 465^5–78^4.

Gneiss, 479^2; defined, 479^9; hornblende, 479^2, 493^9–95^5; quartzose, summary and conclusions, 502^1–3^5; sillimanite, 479^2, 481^7–83^1, 495^6.

Granite, 484^4, 493^9, 495^9, 503^2; description, 496^2–97^5; summary and conclusions, 502^1–3^5.

Graphite, 495^6, 503^7–5^5.

Grenville series, sediments of, 479^1.

Grooves, 476^1.

Hague, 475^9–77^2.

Horicon, 477^2.

Hornblende, 479^2, 494^1, 494^6, 494^7, 496^6, 496^9, 497^5, 497^7, 498^1, 498^2, 498^8.

Hornblende gneiss, 479^2; description, 493^9–95^5.

Hudson, north, 477^5.

Hypersthene, 497^9, 498^5, 500^5, 500^6.

Igneous rocks, summary of evidence of relative age, 487^2–92^8; petrography of, 495^9–501^9.

Ilmenite, 494^1, 498^8, 500^6.

Intrusives, 483^6–84^4; relative ages, 503^1.

Iron ores, 503^7.

Joints, 492^7.

Kames, 472^5.

Kaolin, 494^7, 494^9.

Kemp, J. F., acknowledgments to, 461^6; work on the geology of the Adirondacks, 463^3; cited, 465^9, 481^7, 488^8, 491^6, 501^9, 503^8, 505^8, 506^4.

Labradorite, 494^3, 495^3, 498^2, 498^3, 498^5, 498^9, 499^2, 499^7, 500^5, 500^8, 501^3.
Lawson, A. C., cited, 501^9.
Limestone, 479^2, 479^6.
Limonite, 504^5.
Lower base-level, age of, 469^4.

Magnetite, 494^1, 494^7, 495^4, 496^6, 496^9, 498^2, 498^8, 504^5; nontitaniferous, 505^8–6^7; titaniferous, 499^7, 500^6, 501^3, 501^7, 505^5.
Mica schist, 479^2, 480^9–81^7.
Microcline, 494^2, 494^5, 494^8, 495^3, 496^7, 497^4.
Microperthite, 495^7, 496^8, 496^9, 497^4, 497^7, 497^8, 498^1, 498^3.
Muscovite, 496^6.

Newland, D. H., work on the geology of the Adirondacks, 463^6.
Norites, 500^6.

Oligoclase, 495^3, 497^4.
Orthoclase, 494^8, 494^9, 496^6, 496^8, 497^4, 498^8.

Paleozoic formations, 490^3–91^5.
Paradox Lake quadrangle, location and topography, 464^1–65^4; physiography and glaciology, 465^5–78^4.
Pegmatites, 487^6–89^7, 493^9.
Peneplains, 468^1.
Petrography, 492^9–503^6; of sedimentary rocks, 493^8–95^9; of igneous rocks, 495^9–501^9.
Pharaoh lake, 477^2.
Physiography of the Paradox Lake quadrangle, 465^5–78^4.
Piedmontite, 494^1, 494^3, 494^5.
Plagioclase, 494^2, 494^8, 496^6, 496^9, 498^5, 499^4.
Porphyritic gneiss, 496^8.
Potsdam sandstone, 466^3, 478^6, 490^3.
Preglacial erosion history, summary of, 468^6–69
Putnam creek valley, 466^8.
Pyrite, 495^6, 495^9, 504^5.
Pyroxene, 496 , 497, 499 , 501^3, 501 .

Quartz, 494^1, 494^5, 494^6, 494^8, 494^9, 495^1, 495^3, 495^6, 496^6, 496^9, 497 , 497^4, 497^7, 497^9, 498^1, 498^2.
Quartzite, graphitic, 479^2; shaly, 479^2, 483^2.
Quartzose gneiss, summary and conclusions, 502^1–3^5.

Rutile, 495^9.

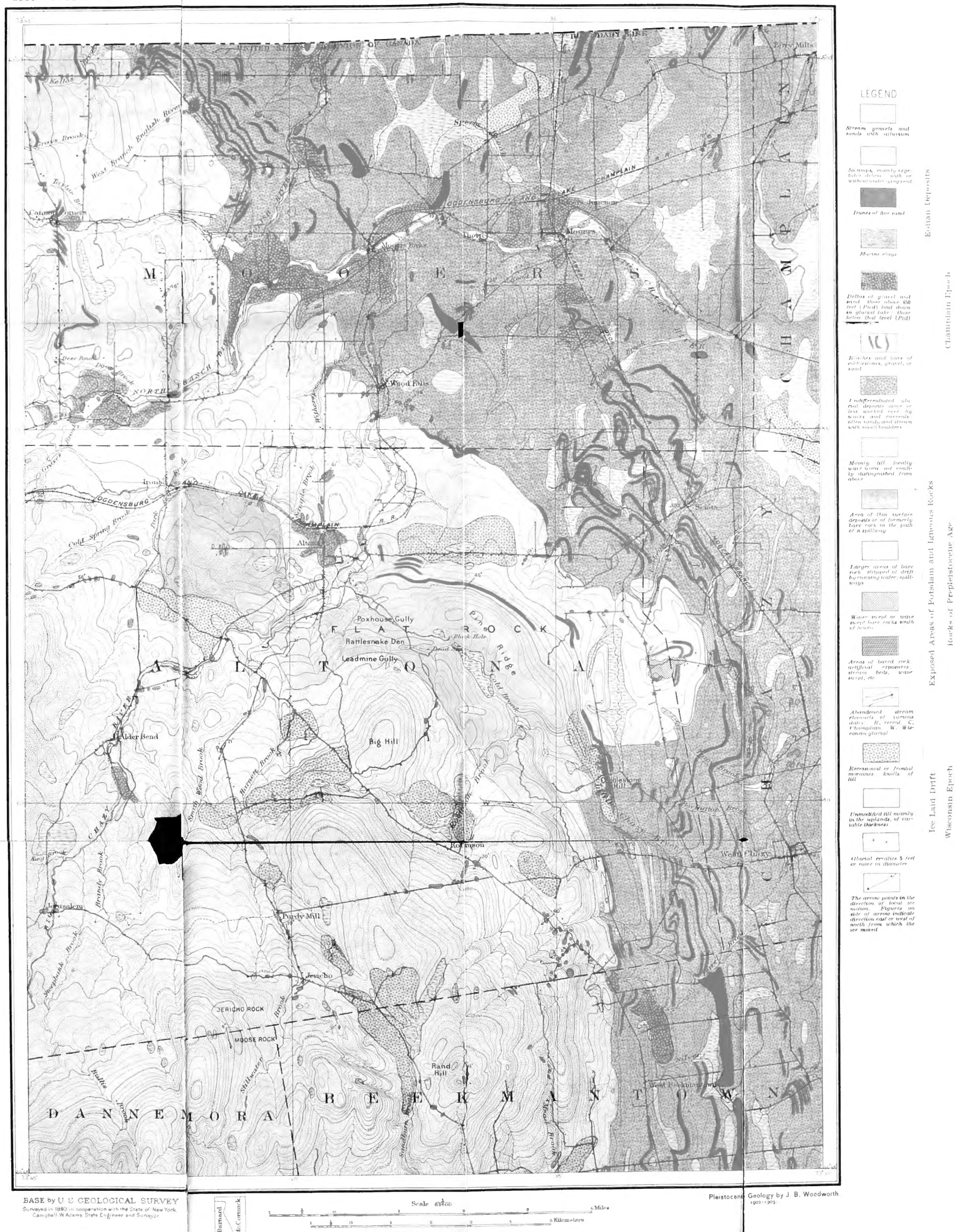
Saussurite, 494^7
Schroon valley, 466^9, 477^2.
Sedimentary rocks, petrography of, 493^8–95^9.
Shaly quartzite, 483^2.
Shear zones, 492^2.
Sherman Corners, valley near, 466^8.
Sillimanite gneiss, 479^2, 481^7–83^1; description, 495^6.
Smyth, C. H. jr, work on the geology of the Adirondacks, 463^4; mentioned, 483^7; cited, 484^8.
Spinel, 498^8.
Stratigraphic relations, summary of, 483^5.
Syenite, 484^8–85^5, 493^9, 495^9, 503^2; description, 497^5–98^4; summary and conclusions, 502^1–3^5.

Ticonderoga, 472^5–77^1.
Titaniferous iron ores, 500^6.
Titaniferous magnetite, 499^7, 500^6, 501^3, 501^7, 505^5.
Titanite, 498^8, 500^5.
Topography of the Paradox Lake quadrangle, 464^1–65^4.
Towner pond, 472^1.
Trap, 493^9.
Trap dikes, 489^8.
Trenton limestone, 490^9–91^5.
Trout brook valley, 466^7, 476^6.

Van Hise, cited, 488^8.

Weinschenk, Ernst, cited, 504^6.
Whortleberry pond, 477^2.
Williams, E. H., cited, 488^8.
Williams, G. H., cited, 498 , 501^8.
Wolf pond, 477^2.

Zeolites, 494^9, 496^7.
Zircon, 495^4, 495^6, 496^6, 498^2, 498^8.



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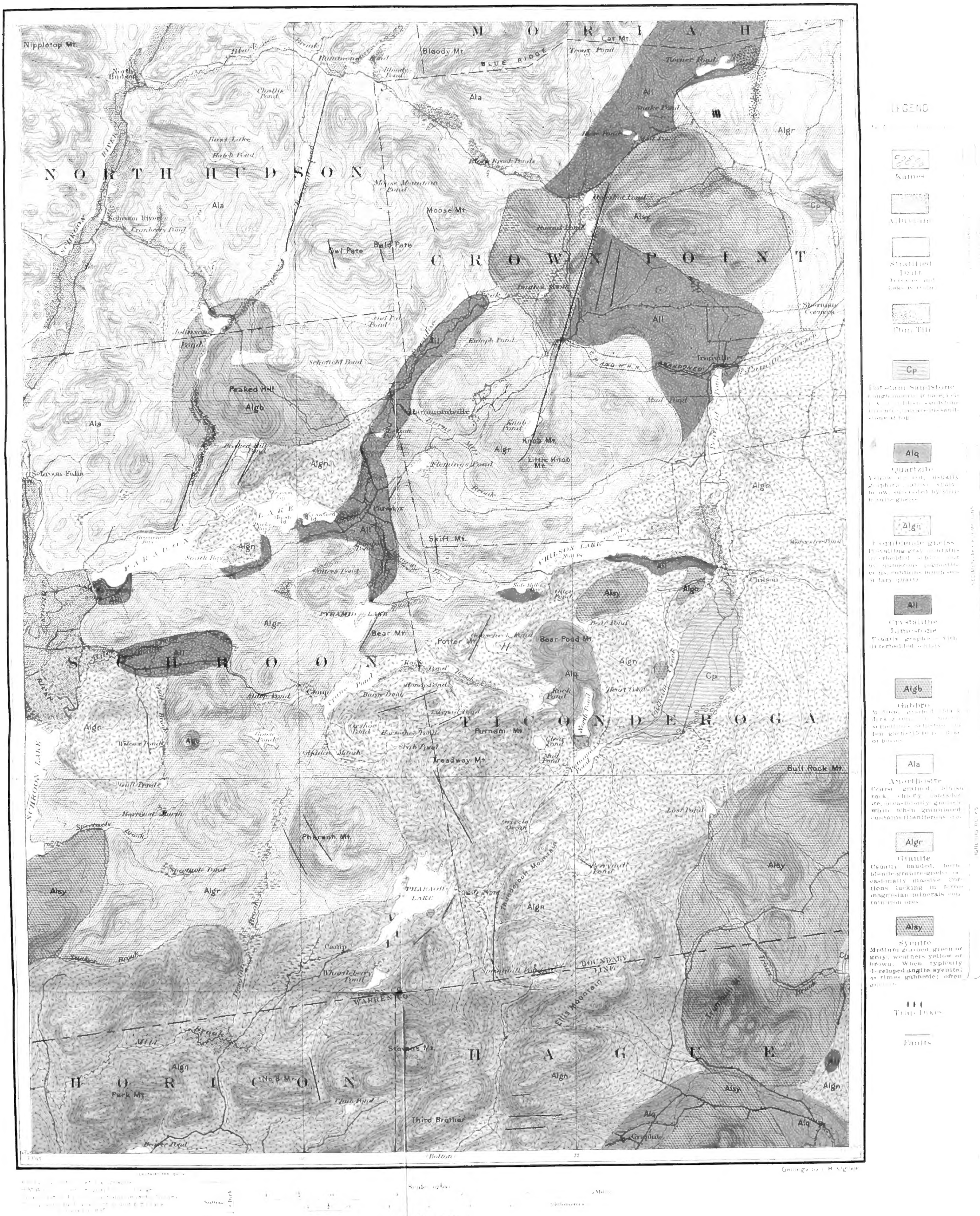
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C R O W N P O I N T
S C H R O O N
T I C O N D E R O G A
H O R I C O N
H A G U E
Nipple top Mt.
Bloody Mt.
Cat Mt.
Trout Pond
BLUE RIDGE
Ala
All
Algr
Algn
Algb
Alsy
Alq
Cp
Moose Mt.
Owl Pate
Bald Pate
Peaked Hill
Knob Mt.
Little Knob Mt.
Skiff Mt.
Bear Mt.
Potter Mt.
Bear Pond Mt.
Putnam Mt.
Treadway Mt.
Bull Rock Mt.
Pharaoh Mt.
Stevens Mt.
No. 8 Mt.
Park Mt.
Third Brother
Ironville
Chilson
PARADOX LAKE
CHILSON LAKE
PYRAMID LAKE
PHARAOH LAKE
BOUNDARY LINE
WARREN CO.
Bolton
LEGEND
Kames
Alluvium
Stratified Drift
Thin Till
Potsdam Sandstone
Quartzite
Hornblende gneiss
Crystalline Limestone
Gabbro
Anorthosite
Granite
Usually banded, horn blende-granite gneiss, occasionally massive. Portions lacking in ferromagnesian minerals contain iron ores
Syenite
Medium grained, green or gray, weathers yellow or brown. When typically developed augite syenite; at times gabbroic; often gneissic
Trap Dikes
Faults
Contour Interval 20 feet